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TRANSACTIONS

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

No. 8.

—1v.
—2p.

MEETING OF APRIL 14-15-16, 1919

PHILADELPHIA

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Volume Eight

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PHILADELPHIA

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RESULT OF ANNUAL ELECTION
OCTOBER, 1918

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SOCIETY OF MOTION PICTURE ENGINEERS

Membership in the Society of Motion Picture Engineers stands for unselfish service to the Industry. Applications for membership are by invitation and endorsement. All checks should be made payable to the Society of Motion Picture Engineers.

All receipts are expended directly to promote the objects of the Society and the interests of its members. There are no salaries or emoluments of any kind.

The following are extracts from the By-Laws:

The objects of the Society are: The advancement in the theory and practice of motion picture engineering and the allied arts and sciences, the standardization of the mechanisms and practices employed therein and the maintenance of a high professional standing among its members.

An Active Member is one who is actually engaged in designing, developing or manufacturing materials, mechanisms or processes used in this or allied arts, or who is interested directly in the art.

Any person of good character may be a member in any or all classes to which he is eligible.

Prospective members shall be proposed in writing by at least one member in good standing, and may be elected only by the unanimous vote of the Board of Governors.

All applications for membership or transfers in class shall be made on blank forms provided for the purpose, and shall be accompanied by the required fee.

The entrance fee for all members shall be twenty-five dollars ($25.00). The annual dues shall be ten dollars ($10.00), payable in advance before the annual meeting (October) of each year. That is, the total fee for the first year, which include the entrance fees and first annual dues, is $35.00 for all members.

PRESIDENT'S ADDRESS

The Society of Motion Picture Engineers has developed into an effective organization. It was less than three years ago when a handful of enthusiastic men at the suggestion of our past president, C. Francis Jenkins, met in Washington to discuss the advisability and possibility of forming a technical body in connection with the motion picture industry. This meeting, as you know, resulted in the formation of this Soc ety at the Astor Hotel in New York in October, 1916. We have been recognized as the authority on technical matters in the motion picture industry and our proceedings, which are issued twice a year, are much in demand for reference. We should continue in our efforts and should include all branches of the industry which should be represented and through this means we should materially increase our membership.

Those who attended our last meeting in Cleveland well remember the instructive and interesting papers which were there read and discussed. Our transactions are now assuming goodly proportions and it is hoped that complete copies of the transactions will be kept convenient for reference.

I am not going to take up much of your time during this session, but I do want to bring two points to you which I feel should be kept constantly in mind; namely, standardization and cooperation.

STANDARDIZATION

One of the drawbacks of the motion picture industry, and this is the experience of all new engineering bodies, is the lack of standardization. We have a very resourceful field before us and while we have made a good beginning, I know we all feel that our activities along this line should increase with each succeeding meeting. Let us, in our recommendations, keep in mind the practical as well as the technical viewpoint, inasmuch as the two go hand in hand. It is very difficult to estimate the dollars and cents that are wasted each year on account of the lack of standardization and likewise it is equally difficult to estimate the savings that we may effect by our efforts to standardize.

COOPERATION

Commercial competition should have no bearing on any papers which we present or discuss. Let us consider why we have become members of The Society of Motion Picture Engineers. Is it our sole wish to join the Society for what we individually can get out of it, or is it our purpose to take a part in the development of this growing industry; to achieve the highest standards in order to materially benefit thereby? Cooperation and good feeling among our members are the only things that will bring the desired results.

The period since the organization of our Society has been a trying one. The whole world has been at war and the period has been one of industrial development rather than of engineering

development and we have all been too busy producing material of one kind or another to assist in winning the war. The Government at Washington has proclaimed to what extent motion pictures have assisted in making the world safe for democracy. Now that the armistice has been signed and peace conferences are being carried on, we can again divert our efforts to a greater extent to the technical fields and solve the problems of standardization which will eventually result in economies in our various departments of activity. In other words, we as engineers, also will have our problems of readjustment.

A subject which should receive our most serious consideration is the work of our various committees. They should show more activity. Members who are appointed on committees are those who are well posted on the subjects covered by the several committees. Therefore the committees are the natural channels through which should originate the problems of standardization and subjects for discussion. It would seem that much of the work of our papers committee could be eliminated if each committee would arrange for papers on subjects which it feels would be most helpful to the members.

I fully appreciate the honor which you have conferred on me by electing me your president. I want to take this occasion to thank those who so unselfishly gave their time and cooperation in connection with the Society work. The result of this meeting will be due mainly to their efforts. I hope that you will individually feel that this is your meeting and that you will leave Philadelphia with the feeling that you have not only profited by attending these sessions, but also that you have been the means of helping other members to solve their problems.

H. A. Campe.

"WHITE LIGHT FOR MOTION PICTURE PHOTOGRAPHY"

By Wm. Roy Mott

Research Laboratory, National Carbon Company, Inc.
Cleveland, Ohio

OUTLINE

1. Introduction
   1–A Relation of Light to Motion Picture Industry.
   1–B Lighting Differences between Theater Stage and Motion Picture Stage.
   1–C Artistic Relation of Light.
   1–D Importance of Great Intensity of Light.

2. Daylight
   Daily and Yearly Variations.

3. White Light from the Flame Arc.
   3–A Spectrum of White Flame Arc.
   3–B Psychological Effect of Color.
   3–C Relation to "Make Up" and to Film Sensitiveness.
   3–D Amount of Light in Relation to Current.
   3–E Amount of Light in Relation to Arc Voltage.
   3-F Relation to Number and Position of Arc.

4. Rapid Developments of High Amperage Flame Lamps.
   4–A Description of Several Types of Flame Lamps.
   4–B Table of Lamps and Trims.
   4–C Conversion of Enclosed Arcs to Flame Lamps.
   4–D Long Life Multiple Trim Arrangement.

5. Moving Picture Flame Carbons.
   Star Core—Metal Coated—Variety of Colors.

6. Discussion of General Advantages of the White Flame Lamps for Photography

7. Special Lighting Effects.

8. Looking to the Future.

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1. INTRODUCTION

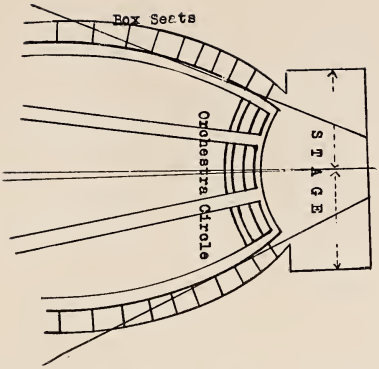
1. Relation of Motion Picture Industry to Light

The famous psychologist, Professor Munsterberg, wrote a few years ago a book on motion pictures, and he there asserted that the production of motion pictures by the best companies had graduated as an *Art* to rank coequal with painting, sculpture and music. By

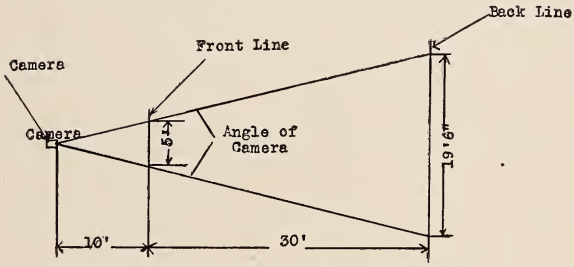
attention to mode and variation of lighting, many new psychological appeals can be made, including the portraying of the thought images in the minds of the characters of the play in a way that cannot be duplicated on the theater stage. Besides being one of the fine arts, the motion picture art has become the greatest educational institution in the world. Very special lighting is needed for scientific films, for ultra-rapid motion picture work, and for the several new color processes in motion picture production. Not only is the moving picture industry the greatest educational institution, but it is also one of our foremost industries. Since Edison's and Jenkin's invention of motion picture devices of only a score or so years ago, the industry has leaped to fourth place in the United States. There is spent annually three to four hundred million dollars by the people of the United States for the privilege of attending the motion picture theaters. The daily attendance is said to average between ten and twenty millions of people. Of the fifty thousand motion picture theaters in the world, there are about twenty thousand in the United States, and as a producing center, the United States is the greatest in the world. The *sunshine* of California has built up a major producing center in and near Los Angeles. (In this center, over $12,000,000 are annually spent for motion picture production, and this gives employment to about 25,000 people.) Again the importance of light in relation to expense of production may be judged from the following statement made by Mr. G. McL. Baynes (of the English Hepworth Mfg. Co., see Moving Picture World, page 2334, December 25th, 1915); "As to photographic difficulties encountered in outdoor work in England, it is ridiculous to say that they cannot make pictures there. *It is true, production is more expensive, perhaps twice as much because we have to wait for the Sunshine.*" Thus in foggy England, the difficulties are much greater on account of poor light than in the West or East of the United States. The invention of the high amperage white flame arc lamps and carbons and of other artificial light sources such as the daylight gas filled tungsten lamps and the mercury arc lamps, have eliminated these expensive waits for sunshine. The home-center of the motion picture industry in the East is again building up rapidly. These new studios are especially to be found in or near New York City, and to a lesser degree near other large centers of population, as for example, Chicago, Philadelphia, Cleveland, etc. Scenic interest, such as at Ithaca and in Florida, is another industrial factor in the location of motion picture plants. The increase in artificial light facilities has been an important economic factor in this Eastern movement which is being accelerated by the continual increase in the extraordinary salaries which are paid the motion picture artists. The cost of production of an average negative of one reel is said to be about $1,000, and of this it is certainly economy to spend one or two per cent. on securing the best lighting.

1-B. LIGHTING DIFFERENCES BETWEEN THEATER STAGE AND MOTION PICTURE STAGE

The lighting differences between the theater stage and motion picture stage are illustrated by Fig. 1, which shows that the theater stage



Floor plan showing theatre stage is very shallow, and has a decreasing width of Back-Ground.



Plan of Motion Picture Stage showing increased depth of Back-Ground

FIG. 1—Theater Stage Compared with Motion Picture Stage

has a broad front line, below which come the footlights, and then a *very shallow back-ground* because the essential action of the stage must be visible to everyone in the audience on both sides of the auditorium. On the other hand, the motion picture photographer can select any point of view, and this necessarily has an enlarging background in the usual case of real scenery. The camera lines in the ground view (Fig. 1) represent limits outside which the lighting units must be placed, except for trick flame lamp used to imitate lanterns and house lamps. In the vertical plane exactly the same rule must be followed in regard to increasing height of overhead lamps for the background. The excellent results from footlights has not yet been appreciated by the motion picture artists.

1-C. ARTISTIC RELATION TO LIGHT

Motion pictures only became commercially successful for entertainments when it became possible to select a subject, stage it with all the startling realism of the spoken drama, and give its photog-

raphy those qualities perhaps best connoted by the term "portraiture." For portraiture effects—Rembrandt, line lighting, etc., control of the position, direction and diffusion of light is necessary. Some lighting forming an oblique angle on the face to the camera gives increased reflection, and aids in preventing flatness. For artistic results, the white flame arc is distinctly superior for securing modelling, atmosphere, definition, half-tone and fine photographc quality in the negatives. Mr. Max Mayers, in his valuable paper on "Artificial Light in the Motion Picture Studio," given at the Rochester meeting of our Society, says "Back lighting is a splendid way of obtaining pleasing and natural results. This is effected by placing the lights well back and directing them toward, but not at the camera, masking the direct rays at the lamp, and preferably using a shielding tube with perfectly dull black interior over the lens barrel, to prevent halation. Thus the figures and objects in the set will be silhouetted, and by the proper front arrangement of reflecting surfaces and well diffused lights at a fair distance, the features and details may be perfectly modelled in shadow, with pleasing highlight relief effected by the rear lights." Later sections will treat further of artistic possibilities with the new lighting means.

1–D. IMPORTANCE OF GREAT INTENSITY OF LIGHT

A large amount of light is required in motion picture work, because of the short exposures (1/30–1/50 sec.), and need for definition. The pictures are only 1″ x ¾″ in size on the celluloid film. These are magnified over 10,000 times in area on the screen and therefore need to be taken with greatest sharpness. There are sixteen pictures per foot and these sixteen are moved through the camera or projecting machine in about one second. (A thousand feet or 16,000 pictures are called a reel and take about fifteen to twenty minutes to run through the machine.) Each picture is brought into exact position with a closed shutter. This shutter is then opened for about 1/30 of a second and the exposure is made. (In case of projection, the eye in this period receives the full impression of the picture and by persistence of vision retains the image perfectly for the next 1/20 of a second during which the shutter is closed and the screen black and the next picture exactly placed.) In the interest of definition and depth of focus, it is highly desirable to work at small lens opening. For instance with the white flame arc lights *f* 5.6 is often used in motion picture studios whereas *f* 4.5 and even *f* 3.5 have been recommended with other sources of artificial light. Some of the flame lamps, with their reflectors and and diffusing screens, can be used to give a light intensity of 10,000 and more candles per square foot, so that even daylight is surpassed if so desired. We will now consider daylight.

The moving picture industry is the only industry dominated geographically by the question of light. While in ordinary artificial lighting 5 and 10 foot-candles is good illumination, yet on the moving picture stage at least a hundred times this should be used. This means a stage illumination of 500 to 1000 foot-candles as a minimum.

2. Daylight

The larger the number of days of good clear sunshine, the lower is the cost of motion picture production, because of the saving of time of high salaried artists. But little has been done as yet to use artificial light in conjunction with *outdoor scenes* for which daylight is ideal except for the interruption of the photography by dark, cloudy days. (In England some use of arc lamps has even been made for outdoor scenes). Even on consecutive clear days there may be a large variation in actinic light as shown in Fig. 2. (See page 128, Sheppard's Photo-Chemistry.)

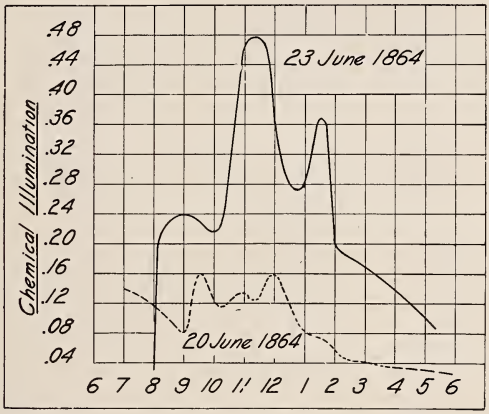


Fig. 2—Daily Variation of Photographic Light with Daylight

For interior scenes daylight must be diffused to avoid outdoor appearances caused by the direct shadows from the sunlight. This diffusion is secured by using prism glass in the roof and sides of the studios. If the studio work for interior scenes is done outdoors then awnings of light sheeting or muslin are used to secure proper diffusion and this is sometimes done in studios with glass roofs, especially if clear glass has been used. A serious objection to daylight in such studios is the hot-house effect, especially in summer. As these glass houses receive continuously one to two horse power of solar energy per square yard of projected area normal to the light, the heating effect is many times greater than with good artificial light alone, because the full amount of artificial light is used intermittently and seldom for more than a total of an hour a day. The artificial light (used generally for side illumination) with daylight should be given by the light of the greatest photographic power in proportion to the energy liberated in the studio. For this reason flame arcs are commonly used with daylight. In the winter daylight is rather poor after penetrating the glass and screening and so dependence is then largely placed on the artificial light. This seasonal variation and hourly variation of sunlight

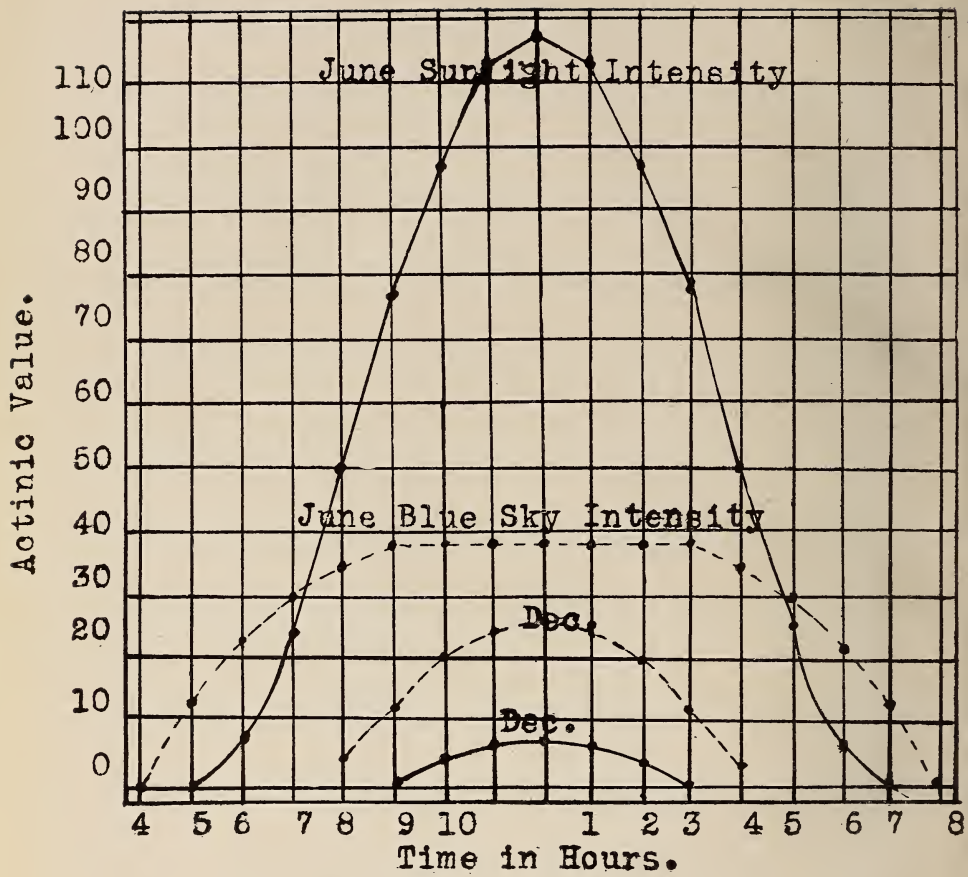


Fig. 3—Average Daily Variation for June and December

and skylight is shown in Fig. 3, taken from Eber's Handbuch der Photographie. Again the changing direction of sunlight has been a serious objection and the studio, known as the Black Maria, of the Edison Company was arranged on wheels so that it could be moved to face the light.

Finally there is one class of interior scenes for which daylight in any form is entirely unsatisfactory. This is in night scenes where sharp shadows and brightly illuminated parts must come in the same picture. Again all motion picture work in actual interiors such as subways, mines, caves, hotels, theaters, churches, etc., must be done with artificial light. This brings us to the vital importance of artificial lights. And of these the closest to daylight photographically is the light of the white flame high amperage arc lamps which will next be considered.

3. White Light from the Flame Arc

3—a. Spectrum

The white flame high amperage arc gives a light which is re-

markably close to daylight in both color and photographic values. Like daylight the spectrum is not entirely continuous, but the effect of being practically continuous is obtained by the enormous number of light giving lines in every part of the spectrum, including the ultra-violet which with the white flame arc is very similar to that given by sunlight.

In Fig. 5 is shown in the outer parts the spectrum of a white flame arc (25 amperes) in the region photographically important

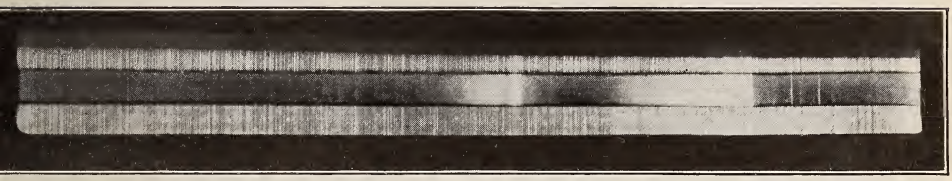


Fig. 5—Spectrum—Outer Two Snowwhite Flame Arc—Inner Carbon Arc No Flame Material

for the common materials. The pure carbon arc for the same region is shown by the middle spectrum which has marked gaps between the cyanogen bands (the cyanogen bands are due to the reaction of carbon and nitrogen at high temperatures). This duplication of daylight is so good and the intensity of light is so great that this light is being used by large clothing concerns as a reliable substitute for daylight in making dye fading tests. In fifty hours of testing with the flame arc, dyes are faded to the same degree as by about three weeks of ordinary daylight in June in Cleveland. The white flame arc is also used for color matching.

3–B. PSYCHOLOGICAL VALUE OF COLOR OF LIGHT

It is a part of the higher management of motion picture producers to give the actors and actresses a background of reality and not of ghastly unreality. "The living interpreter must have the living scene to do his best." And so it is now recognized by motion picture producers that pleasant scenes need pleasant light in order to get the best out of the artists, as witness the use of music. White light is the best for ordinary drama and comedy. A blue or blue-green light is especially good for very sad scenes, such as death-bed scenes. Mr. Edward L. Simons (Trans. I. E. S. 6, p. 295, Jan. 1911), at a time even before the use of flame arcs, pointed out the effect of blue-green light on the actors by saying "but without the arc lamp, it would be pretty hard to go through a real love scene, because everybody would look sick." Hence the value of the red content of the white light is of great importance to motion picture productions (although photographically of no value for ordinary purposes), it is of value in giving the artists a suitable environment for their best artistic expression. Much of the modern film is sensitized to long wave lengths and then the red and yellow light are important.

3–C. RELATION OF COLOR TO "MAKE-UP" AND FILM SENSITIVENESS

In make-up the motion picture artist soon learns that red will photograph black because the ordinary film is not sensitive to red light. For this reason the make-up of a moving picture artist should not have rouge on the cheeks (and it is best to avoid having gold-filled teeth). On the other hand an excessive amount of white clothing should be avoided as this may give rise to halation which results in a blur. Hence yellow, gray and other colors of clothes are used. This halation needs to be watched carefully with the lights having low latitude on the photographic plates. It is interesting to note that the light of the white flame arc shows a very wide latitude on films. This means the picture will show parts highly lighted and dimly lighted with clear definition.

In regard to film sensitiveness the ordinary motion picture film has a maximum sensitiveness in the violet with considerable sensitiveness in the blue and ultra-violet and much less in the green and yellow, and no sensitiveness in the red. Some motion picture laboratories are making orthochromatic films fairly sensitive to yellow light. For panchromatic photography and color photography, of course, all parts of the light are used. Because of the use of a yellow screen with these, special flame carbons can be used not only to give more light, but such light that a screen of better transparency can be used. This, of course, is very important because color photography film calls for a great deal more light for motion picture work than ordinary films. For motion picture production the yellow flame carbons with special screens have been found very good. Calcium fluoride is used and gives a spectrum rich in red and green bands with very little spectrum yellow.

3–D. AMOUNT OF LIGHT IN RELATION TO CURRENT

The flame arc shows a rapid increase in actinic light with increase in current. In fact the flame arc with doubling of the current at the same arc voltage increases its photographic effect not twice but three to four times. This makes it profitable to use the flame arcs at high amperages of 15–25 to 35 amperes. In some cases much higher amperages have been used. The effect of amperage on amount of actinic light is shown in Fig. 6, which also shows the advantage in effect that the flame arc has over the enclosed ordinary arc. These sets of curves in Fig. 6 were obtained with single arcs on 110 volt circuit, but with the new type of flame arc having two arcs in series on 110 volts the efficiency of the flame lamps is often increased from 40 to 60% over that of a converted lamp with a single flame arc on 110 volts. The enclosed arc lamp soon reaches a limit of current because of the dangers to globe melting down or if a very large globe is used then the amount of air at the start decreases the initial efficiency, which is very important in motion picture work because the actual scenes are short and usually last from ten seconds to a minute or two. On a 220 volt circuit, it is now customary to use 2 or 4 flame arcs in series and this compares favorably with the 220 volts enclosed arc lamps under average con-

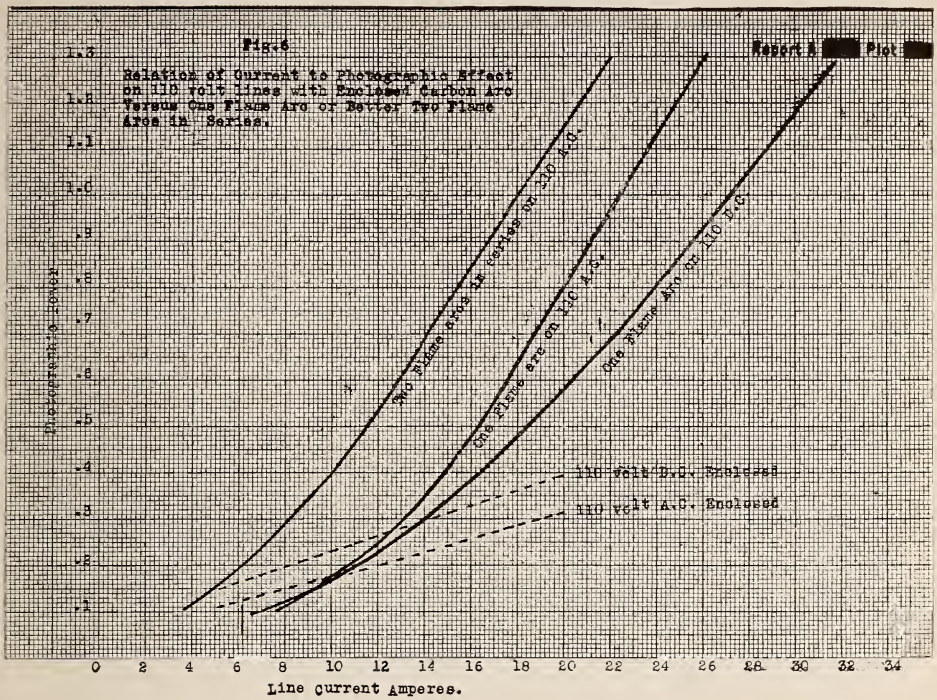


Fig 6—Relation of Current to Photographic Effect on 110 Volt Lines with Enclosed Carbon Arc versus Single and Twin Flame Arcs

ditions. From a series of tests of a direct current flame arc lamp, I have deduced the following approximate equation for photographic efficiency as regards effect on solio paper for a single direct current flame arc. C is current and V is arc voltage within moderate limits (40 to 80).

Photographic efficiency $= KC^{1.8}(V-23)$

On alternating current efficiency increases as $C^{2.2}$

The flame arc also increases in candlepower more rapidly than the current, but this phase of the matter does not need to be enlarged upon here. The color of light increases toward the short wave lengths faster than the long wave lengths with increase in current. With increase in current the blue light increases more than the green and the green more than the red.

3—E. AMOUNT OF LIGHT IN RELATION TO ARC VOLTAGE

We will very briefly consider the relation of photographic effect on solio paper to arc voltage (see Fig. 4) keeping the current constant. The following results were obtained by using a 330 volt direct current circuit with the trim of a 10 mm x 305 mm lower flame positive and a 12½ x 305 mm upper (½ x 12″) cored enclosed arc standard negative upper. The data shows the great advantage of using two flame arcs in series on 110 volts. The working equa-

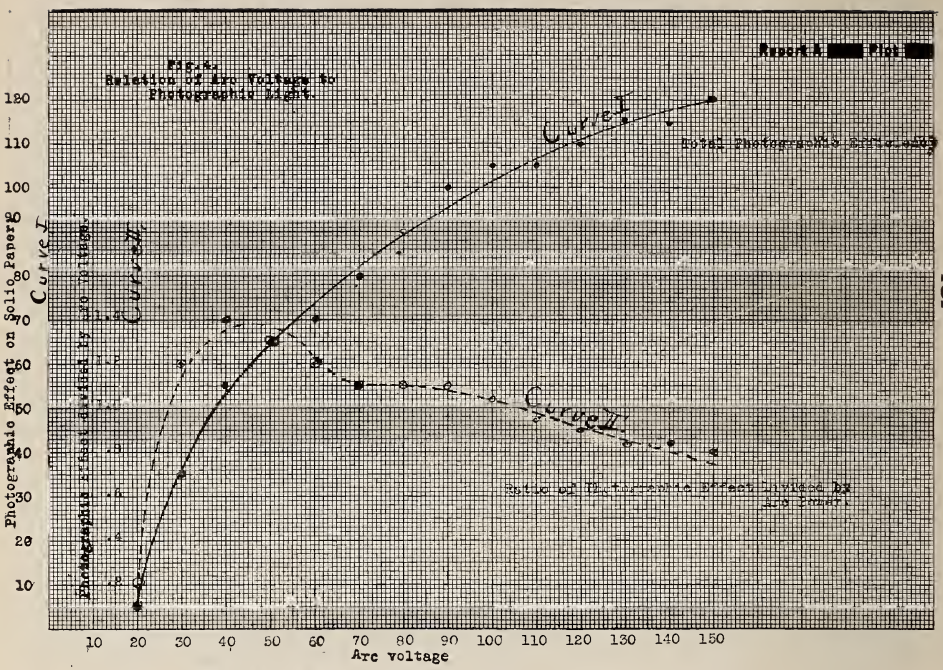


FIG. 4—Relation of Arc Voltage to Photographic Light

tions of the data can be reduced to the following approximate, empirical formulas.

1st, from 0 to 60 arc volts at 25 amperes,

Photographic Power $= 5.1\ V - 78 - .044\ V^2$

From 60 to 150 arc volts at 25 A

Photographic power $= 1.47\ V - .0045\ V^2$

TABLE I

Volts Col. A	Photographic effect on Solio paper Col. B	Energy efficiency $\left\{ \frac{B \text{ Photographic effect}}{A \text{ Arc voltage}} \right.$
20	5	.2
30	35	1.2
40	55	1.4
50	65	1.3
60	70	1.2
70	80	1.1
80	90	1.1
90	100S	1.1
100	105	1.05
110	105	.95
120	110	.9
130	115	.85
140	115	.85
150	120	.80

S means standard of reference.

Analysis of the above table shows that the use of two flame arc in series is very efficient. This also has other advantages. namely that the power factor can be raised on A.C. from about .90 with a single arc to even .95 for the twin arcs. Also the volt ampere characteristic is materially improved so that as much as nearly 90% of the line power taken can be thrown into the flame arcs even on multiple circuits of 110 volts with satisfactory steadiness.

3–F. RELATION TO NUMBER AND POSITION OF ARC

With two flame arcs in series on 110 volts steady operation can be secured with 45 volts at each arc or with 90 volts of the 110 line volts in the light producing arcs. With a single flame arc on 110 volts about 60 volts are used in the arc so that the twin arcs have about 50% better power utilization over the single arc. Also the power factor and arc stability are improved by operating two or three flame arcs in series on 110 volts. It is not practical to operate more than a single enclosed arc on 110 volts because its starting arc voltage of 40 volts is over twice as great as the starting arc voltage of the flame arc of 15 to 20 arc volts. This difference is further illustrated in Fig. 7, showing an Aristo enclosed arc lamp, the same converted to burn flame carbons and the twin arc Wohl lamp. (This Fig. 7 was prepared by Mr. Ben Perris.)

A vertical flame arc is generally preferred, but the arc will burn well in a great variety of positions. In general, flame upper carbons and flame lower carbons are used in motion picture flame lamps so that the lamps can be used on either direct or alternating current and without any regard to polarity if it is direct current. This

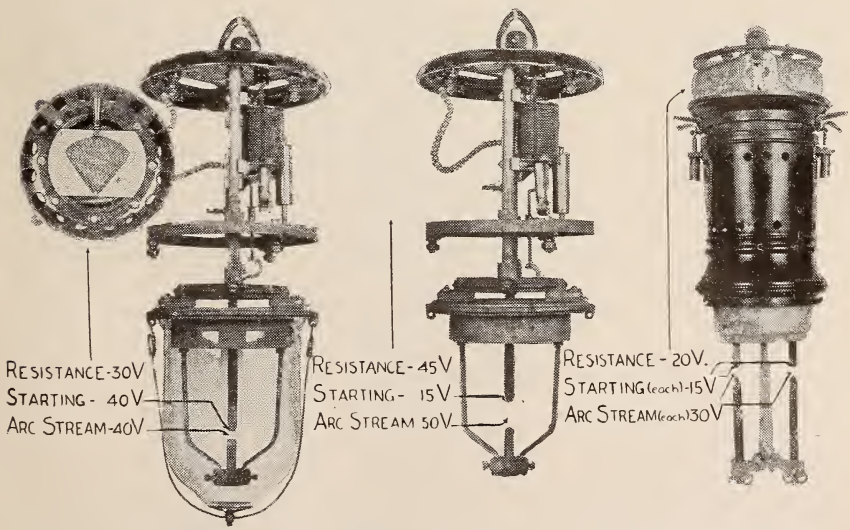


FIG 7—Aristo Enclosed—Aristo Converted to Flame Carbons—Twin Arc Wohl—Shows Voltage Distribution

arrangement is different from the photoengraving field where a very common trim is a neutral enclosed arc upper carbon with a *white flame positive lower*. In this case the flame carbon must always be made positive because the flame chemicals travel through the arc stream from the positive crater to the negative crater. It is the flame materials that produce the light and wrong polarity or pure carbon open arc gives about one-sixth the photographic light of the white flame arc. However, a positive flame upper carbon gives better efficiency with a flame negative lower as against a neutral negative lower.

On alternating current, both carbons should be flame carbons, as here the flame material feeds from both electrodes, and so this arrangement gives the maximum efficiency. The use of reactance ballast on alternating current lamps in place of resistance ballast increases greatly the efficiency of a white flame arc for equal power in the arc, and gives from 50 to 100% more light for equal power on the line. With reactance ballast on two or three flame arcs in series on 110 volts, the overall power factor is better than .85. Three flame arcs in series on 110 volts with metal coated carbons gave but very little if any more efficiency than two flame arcs in series.

We will now consider some of the typical flame lamps used in motion picture studios.

4. Rapid Developments of High Amperage Flame Lamps

4-a. Description of Several Types of Flame Lamps

Special flame lamps have been developed to operate on A.C. or D.C. and in series on 220 volts or in multiple on 110. This makes the lamp of universal use, and calls for no special attention to the electrical conditions. The resistance of the flame lamp to mechanical shocks, electrical shocks such as overvoltage and to bad weather conditions, has made it universally used for outside (of studio) motion picture work. Combined with all these advantages is the remarkable small weight of these lamps. For instance, some of the twin arc lamps weigh no more than 20 pounds for lights giving 8,000 or more horizontal candlepower, and with the light of a little greater actinicity than daylight. The amount of light is probably greater in proportion to weight than any other artificial light used in motion picture studios. Further improved design can greatly reduce this weight.

We will now show briefly figures of a number of typical high amperage flame lamps. The following flame lamps are commonly used in motion picture work: Allison and Hadaway, Aristo, Bogue, Chicago Stage Lamp, Joyce, Klieglight, Macbeth, Scott, Simplex, Sunlight, Universal, Wohl and others. As there is no article or book where these types have been shown collectively, I believe the following figures will be of interest.

The Aristo lamp, Fig. 7, is an enclosed arc lamp which has been much used by portrait photographers and in motion picture studios.

The motion picture studios now use in the Aristo lamps, white flame carbons ½ x 12″ upper with a ½ x 6″ lower *with or without the globe*. The greater diffusion of the light and reliability of the flame arc immediately found great favor with the photographers of motion picture concerns when demonstrated a few years ago by Mr. A.D. Spear, June, 1912, at Edison studio. The amount of light with 28-A and 63 arc volts with flame carbons was 5130 *mean spherical candle-power* in the tests in our laboratories at Cleveland.

The Allison and Hadaway lamp is a twin arc designed especially for portability in a suitcase form. There is also made by this company, a diffusing cabinet with flame lamp and a small amateur flame lamp with shunt control to greatly raise the current at the time of taking the pictures. The horizontal candlepower of the 15 ampere flame lamp is said to be 8,000. Fig. 8 is a hanging lamp of the Allison and Hadaway type.

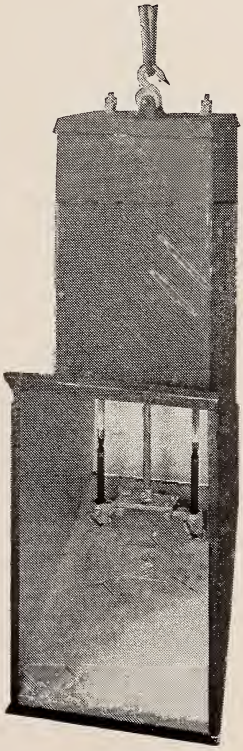


Fig. 8—Allison and Hadaway Twin Arc Hanging Lamp

The Chicago Stage lamp, Fig. 9, is unusual in having the flame carbons at right angles.

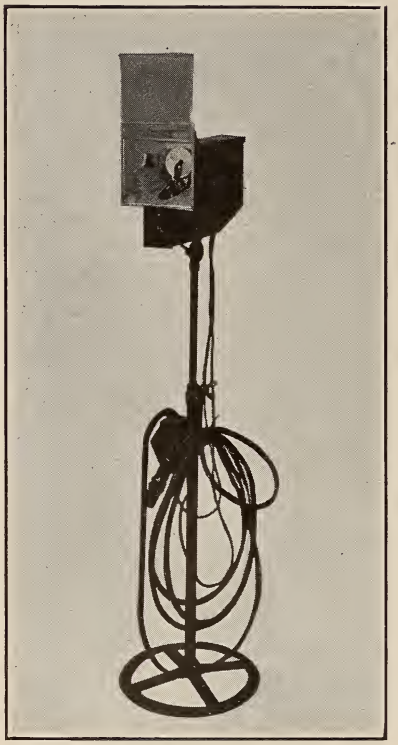


Fig. 9—Chicago Stage Lamp

The Joyce flame arc lamp has been used somewhat in industrial moving picture work.

The Klieglight, Fig. 11, is a high amperage (30 to 40 amperes) lamp, *with horizontal carbons*. The lamp is mounted on a pedestal with casters, and is used for side lighting. The lamp is very powerful, and so is usually diffused by a large glass screen. A low weight lamp with vertical flame carbons is also made. The portable Klieglight is shown in Fig. 10.

The Macbeth Co. is well known in the photo-engraving field, and have recently produced a tilting lamp, which is apparently of considerable greater efficiency than their usual photo-engraving lamp. The lamp is designed so that the light can be directed to any part of the stage, both vertically and horizontally. The tilting lamp is designed to burn on A.C. and D.C. and, in case of 220 volts, two in series.

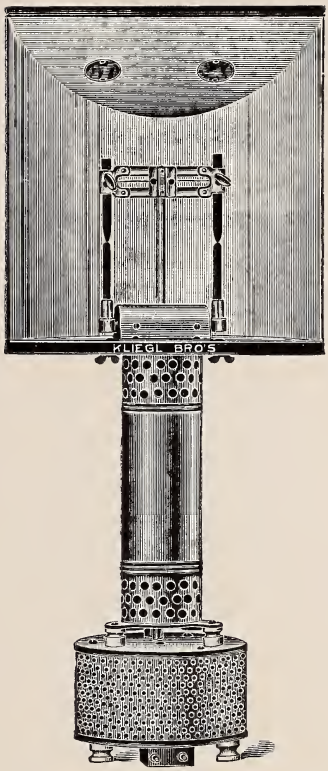


Fig. 10—Klieglight Portable

Fig. 11—Klieglight Stand. 25-35 Ampere with Horizontal Flame Carbons

The Scott lamp, Fig. 12, is a revival of the inclined gravity feed lamp at 15 to 20 amperes, and has two arcs in series in each lamp.

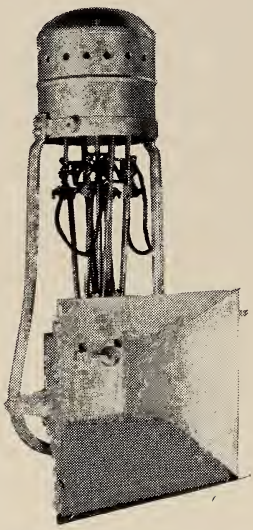


Fig. 12—Scott Hanging Lamp, 15-20 Amperes—Inclined Trim Twin Arcs

This lamp is especially used for overhead lighting, and in a stand form for side lighting. These lamps give a greater effect by 40% than some of the flame arcs having only one arc on 110 volts.

The Simplex lamp is a twin flame lamp which is very portable and can be carried around in a suitcase. This lamp is designed for 15 to 25 amperes.

The Universal or Majestic lamp has two flame arcs in series, and these are placed next to the economizer. The lamp can easily be directed to throw its light to any part of the stage.

The Wohl Duplex hanging lamp is shown in Figs. 7 and 13. This lamp has two flame arcs in series, and our laboratory tests show a mean spherical candlepower of 6,700 with no reflector with the lamp taking 30 amperes on 115 line volts (direct current.) With the reflector, the horizontal beam candlepower is 22,000, according to tests made by Mr. Perris of our laboratory. In motion picture studios these lamps are provided with suitable woven glass diffusing screens or large tracing cloth diffusing screens. The Wohl Broadside, Fig. 14, is a stand lamp taking 30 amperes with four arcs in series on 220 volts or 60 amperes on 110 volt line with two pairs of series arcs. A very portable low weight lamp is also made. A complete description of all the American lamps would fill a book, so we will pass on to foreign lamps and spot lamps.

The foreign makers of white flame lamps have lagged considerably behind the American manufacturers. An English flame lamp

called Truelight, is interesting because four arcs are used in series on 220 volts, with the current reversing direction at each arc and carbons changing size to maintain a focusing effect. Some of the early

Fig. 13—Wohl Overhead

Fig. 14—Wohl Stand Lamp

German flame lamps are shown in Eder's Handbuch der Photographie, page 452. They can be of no importance compared with the American lamps.

Another type of flame lamp is the spotlight lamps operated usually by hand. These are used in the same way as the ordinary theater spotlight lamps, but unlike the theater lamps, the carbons used should be the white flame photographic carbons or the white flame searchlight carbons. Some movie directors have told the

4—B. TABLE OF WHITE FLAME LAMPS USED IN MOTION PICTURE STUDIOS

Flame Lamp	Amperage	Chief Lamp Characteristics	Flame Carbon Trims Upper	Flame Carbon Trims Lower	Number and Position of Flame Arcs
Allison & Hadaway	15 A–25 A	Suitcase Portable	½ x 4″ W. F.	⅜ x 4″ W. F.	Twin Vertical
Aristo	28 A	Converted Enclosed Arc	½ x 12″ W. F.	½ x 6″ F. W.	Single Vertical
Bogue	25 A	Stand (Photo-engraving)	½ x 12″ W. F.	½ x 6″ W. F.	Single and Twin Vertical
Butler Super Power	15 A to 55 A	Widely Adjustable Amperes	½ x 12″ W. F.	½ x 6 ″ W. F.	Single Vertical Adjustable
Chicago Stage Lamp	25 A	Right Angle	⅜ x 12″ W. F.	½ x 6″ E. A.	Right Angle Arc
Converted Enclosed Arc	15 A to 70 A	Shunt Adjustable	½ x 12″ W. F.	½ x 6″ W.F.	Single Vertical
Joyce Flame Arc	25 A	Stand (Photo-engraving)	½ x 12″ E. A.	⅜ x 12″ W. F.	Single Vertical
Klieglight	15–30–40 A	Portable and Heavy Stand	½ x 4¾″W. F.	½ x 4¾″W.F.	Twin Horizontal
Macbeth Tilting	25 A	Stand Tilting	½ x 12″ W. F. (A. C.)	½ x 12″ W.F.	Single and Twin Arc Tilting
Scott	15–20 A	Inclined trim	⅜ x 11-32 ″x12″ W.F. (D.C.)		Twin Inclosed Trim
Simplex	15–25 A	Suitcase Portable	½ x 4″ W. F.	⅜ x 4″ W. F.	Twin Vertical
Stage Spotlight	50–100 A	Spot lighting	½ x ⅝″ x 6″ W. F.		Single Flame Spotlight
Sunlight	120–150 A	Searchlight	⅝″ x 12″ W. F.	½ x 7″ W. F.	Flame Searchlight
Universal	15 A	Tilting	⅜ x 12″ W. F.	½ x 12″ W. F.	Twin Arc Tilting
Wagonhoarst	30 A	Reactance A. C.	½ x 12″ W. F.	½ x 6″ W. F.	Twin Arc Vertical
Wohl Tilting	25 A	Portable Tilting	½ x 6″ W, F.	½ x 6″ W. F.	Twin Arc Tilting
Wohl Duplex	30 A	Side and Overhead	½ x 12″ W. F.	½ x 5″ W. F.	Twin Arc Vertical
Wohl Broadside	30–60 A	Powerful Stand	½ x 12″ W. F.	½ x 5″ W. F.	Four Arcs Vertical

Abbreviations: A = Amperes. W. F. = White Flame. E. A. = Enclosed Arc.

writer that using the white flame photographic carbons increased the photographic light about six times compared with ordinary projector carbons. The white A.C. projector carbon is not as efficient for studio lighting as the white flame photographic carbon. The flame searchlight has also entered the motion picture field with great success. It is often operated fifty feet away, and with currents of 120 to 150 amperes. We will next consider homemade flame lamps. Electricians in motion picture studios have to continually devise new effects for simulating lanterns, indoor lamps, fires, etc. In general, it is a great mistake to make an article if it can be found on the market; but there are times when it is an advantage to know how to make a flame lamp out of other lamps. This we will next consider.

4-C. CONVERSION OF ENCLOSED ARCS TO FLAME LAMPS

For some purpose a cheap lamp with adjustable current for changing the amount of light is convenient. In Figs. 15 and 16 are

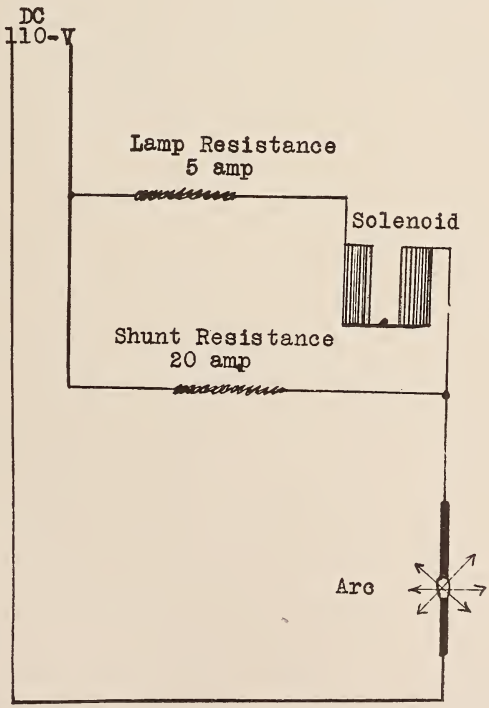


Fig. 15—Conversion Diagram for Changing D.C. Enclosed Arc Lamp to Adjustable Flame Lamp

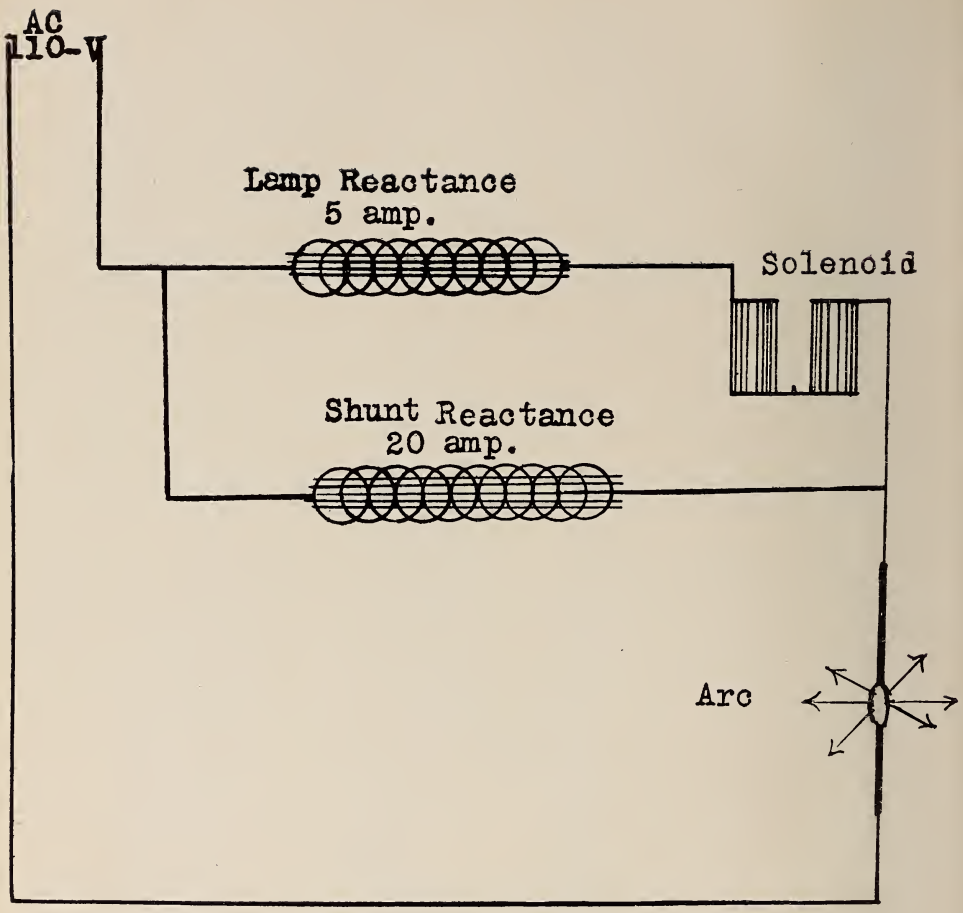


FIG. 16—Conversion Diagram for Changing Alternating Current Enclosed Arc Lamps to High Amperage Flame Arcs by Reactance Shunt

shown the electrical arrangements that the writer devised several years ago for doing this. The globes should be removed from the lamps and where necessary the lower holders should be made rigid. All the electrical wiring should be arranged on one side of the arc, and then a resistance (or reactance can also be used on A.C.) is connected in shunt to carry 15 to 20 amperes at 50 volts around the lamp resistance and solenoid ordinarily taking only 5 to 7½ amperes. Half-inch white flame carbons, metal coated at the holder ends, give excellent results. It is easy to work two converted enclosed arc lamps with the two flame arcs in series on 110 volts.

4-D. LONG LIFE MULTIPLE TRIM ARRANGEMENT

A long life multiple trim arrangement for photographic white

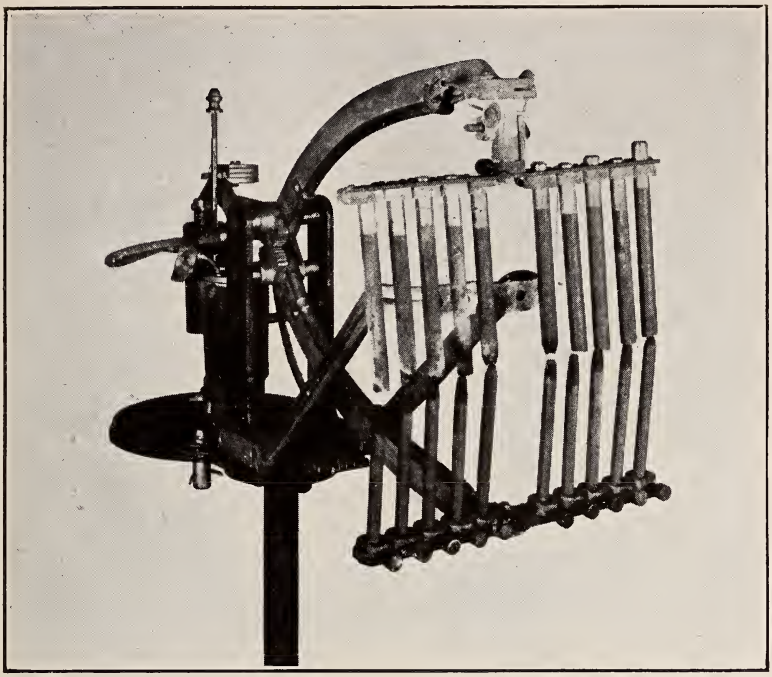


Fig. 17—Long Life Multiple Trim Arrangement

flame lamps is shown in Fig. 17, where a holder having ten trims was operated on a Macbeth photographic engraving lamp with its reflector detached. For many purposes doubling the trim would have great advantages, and the writer believes a number of arc lamp companies will shortly put out lamps with multiple trims. They would be especially useful for overhead lighting and for blue printing.

We will now turn to the consideration of the flame carbons which are the heart of the light production. A picture of the flaming arc is shown in Fig. 27.

5. Motion Picture Flame Carbons

The chief carbon used for photo-engraving and photography is the white flame carbon of which over a million a year are now being sold for this class of work. In the larger sizes a special star shaped core is used. The color of the light can, where necessary, be changed to suit the exact requirement without buying a new lamp or even a new screen, because other flame carbons of different colors are available for these lamps when they are needed. The white flame is strictly a snowwhite light with a spectrum (Fig. 5) full of lines in its every part. This is most generally used. The pearl white is a light a little more suited for panchromatic and color photography. The

color of its light is very close to that of ordinary sunshine. The yellow flame carbon gives a light rich in red and green, but having comparatively little spectrum yellow or blue. The sensation of yellow light is produced by the combination in the eye of the red and green light. The violet in this light is fairly strong. The red flame arc gives a light rich in red and in spectrum yellow, and has a fair amount of blue. The so-called "blue" flame carbons are designed to be especially rich in far ultra-violet beyond 3000° Angstrom units. This far ultra-violet is practically absent in sunlight and likewise in the white flame arcs ordinarily used in photographic work. The near ultra-violet light is very important photographically with sunlight and skylight, and with the white flame arcs. The ultra-violet of the white flame is largely in the region longer than 3500° Angstrom and it efficiently goes through ordinary glass.

An important improvement has been the use in photographic lamps of metal coated flame carbons, especially on the holder end. This metal coating reduces the holder drop in voltage from about half a volt to 1/20 of a volt so that a holder designed for 5 ampere use can, with metal coated carbons, be used at 20 and 30 amperes with long, excellent service.

American white flame carbons, both in our tests and those throughout the United States have shown 10 to 15 per cent better efficiency of light and longer life on the average than the foreign carbons. This is because of superior knowledge and skill that the American carbon manufacturers have as regards the making of these flame carbons. This condition of superiority has been maintained for several years.

6. Discussion of General Advantages of the White Flame Lamps for Photography

The following ten points repeat a few of the advantages of the flame lamps for photographic artists; the greatest efficiency; best color duplicating daylight; instant response when the current is turned on; less unsteadiness from fluctuating line voltage; wearing part of smallest cost per unit; most rugged to all kinds of mechanical and electrical abuse and to adverse weather conditions; lowest cost of installation and operation; can be used for spot lighting or with screen for diffuse lighting or with reflector for indirect lighting; largest candlepower per single unit and maximum portability in proportion to candlepower.

7. Special Lighting Effects

In considering the lighting of moving picture studios, we will consider first over-head lighting and then side lighting. In regard to *overhead* lighting there are two classes—diffuse and concentrated. The diffuse lighting is often obtained in the glass studios by use overhead of flame arcs which occupy only a small area and allow considerable of daylight to enter the scene. The concentrated overhead lighting is secured by mounting in a large reflector a score of

Fig. 18—Aristo Lamps with White Flame Carbons at Edison Co. (This was the First Moving Picture Company to Use White Flame Carbons. Mr. A. D. Spear First Demonstrated the Use Here in June, 1912.)

Fig. 19—Edison Studio Lighting with Blue Bulb Gas Filled Incandescent Lamps

Fig 21—Miss Anita Stewart Redeeming Light Setting at Vitagraph

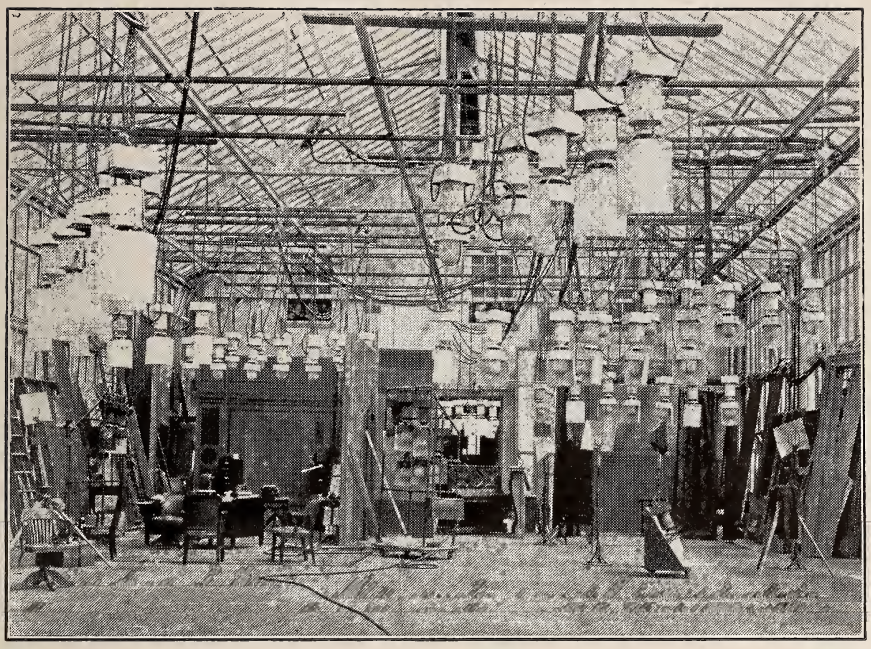


FIG. 20—Typical Studio Setting for Two Scenes at the Vitagraph Co. Using Flame Lamps Designed by Mr A. Ross. Twenty Flame Lamps at 20 Amperes are Used for Average Set

flame lamps or by the use of very powerful spot light or flame searchlight. In overhead lighting with flame arcs for the Edison studio

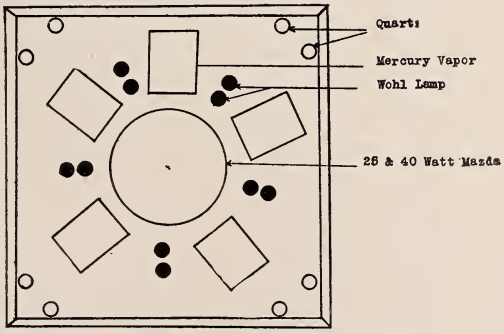


Diagram of the ring showing the approximate location of the Lighting units.
The large circle in the center represents a metal cone carrying 300 25 & 40 watt Mazda Lamps.

FIG. 22—Overhead Lighting at Madison Square Garden for Eight Cameras Simultaneously

is shown in Fig. 18, and for the Vitagraph studio in Figs. 20 and 21. In Fig. 19 there is shown overhead lighting with the blue bulb daylight incandescent lights in the Edison studio. Other modes of lighting are shown in Figs. 22, 24, 25 and 26.

For *side lighting* powerful flame lamps on stands with wheels are universally used. A well known illumination expert for motion pictures, Mr. Mayer of Wohl & Co., states that the best lighting for moving picture stage is ordinarily given by using 50% more side lighting than top lighting, and that the so-called L arrangement

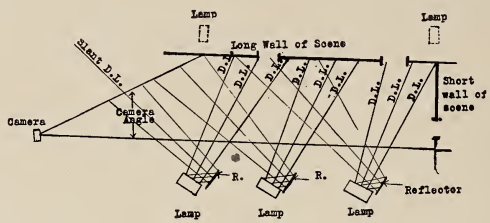


FIG. 23—Typical Side Lighting for Usual L Scene

(Fig. 23) is generally more effective for lighting than the box arrangement. The side lighting should have contrast to give the proper perspective. The angular sweep of the camera is usually such that the distance from camera divided by two gives the width of the operating field (close-ups of 4 feet cover an approximate width of 2 feet.)

The diagram, Fig. 23, illustrates roughly, the *L* arrangement. In this arrangement there are shown the long wall of the scene to the short wall with the camera opposite the short wall and a number of side lights. The overhead lighting is not shown. Small reflectors are used with the side lamps to give slant light coming back toward the camera, but of course *not into it*. This gives a good reflection on surfaces sidewise to the light because the light is reflected so obliquely that a large amount is carried to the camera from side surfaces, and this arrangement gives the much desired line and Rembrandt effects, or as better known to the motion picture artist as molding and modelling effects. The working area of such a stage is therefore bounded by the long wall and short wall and the camera line, outside of which the lights must be. The distance outside should be sufficient to avoid harsh changes due to inverse square law.

The use of real scenery in place of painted scenery gives, of course, the best results. Real scenery should be lighted from the side. Painted scenery should be lighted directly from the front with the light striking nearly perpendicular. If the scene is set up with painted scenery, two sets of lighting should be used, one for the foreground and the other for the painted scenery. This same principle applies to panorama where near objects are lighted in one way and the panorama in a different way to give suitable blending of the illusion.

In lighting it is well to get a suitable blending of the direct light and of the diffuse light. Nature's rule is half and half. The diffuse light is so advantageous in cutting out the harsh sharp black shadows and giving what is known technically as luminous shadow effects. Diffuse light can be secured by indirect light as well as by diffusing screens. The intensity of the light should photographically be very high in order to get the camera to operate satisfactorily with *f* 5.6. The flame arc can be used with a camera lens at *f* 5.6 to give good lighting on a small stage with 20 kw. The jump from *f* 5.6 to *f* 4.5 or even *f* 3.5 makes a big difference in the definition and clearness of the picture. The depth of focus can be maintained better, of course, with *f* 5.6, and because of the important artistic value of the background and the large distances with rapid movements that should be covered, it is highly desirable to work with a good depth of focus. With the flame arc the high concentration of light can be easily controlled as well as the direction of light. This convenience of control of the amount and direction of light are necessarily of the highest importance for free artistic expression on the part of the directing geniuses. In general, the motion picture stages will use with flame arcs the following amount of powers having the lens at *f* 5.6.

Small Stage	20 kw.	4 to	6 flame lamps.		
Medium "	50 "	10 "	16 "	"	(See Fig. 1)
Large "	100 "	20 "	32 "	"	

Using the larger openings of lens *f* 3.5 as low as 20 kw. with flame arcs can be used to secure the illumination of large stages. As the amount of light varies with the reflecting surfaces and is inversely as the square of the distance from the light sources it is not easy to give exact information without going into too elaborate detail. Also multiple reflection can in partly closed spaces greatly increase the illumination. (See Fig. 25 and 26.)

The artistry of the motion picture field is advancing so rapidly with so many new and complex changes that it is rather hard for an amateur like myself to keep track of even their main drift. Among the recent innovations has been the production of plays with the background subdued so that instead of the usual "close-up" the faces of the players in tense scenes are accented throughout the entire production of the play. As, for example, in the play "The Golden Chance." In this case, the background is subdued to such an extent that the characters in the foreground appear to stand out in steroscopic relief.

In another arrangement an intensely lighted background is used to cause the players to stand out in sharp shadow-like relief. In still other cases the immense control of intensity of light gives a power of securing the sudden appearance or disappearance of an actor in trick and dramatic pictures and to aid greatly in securing such peculiar effects as double exposure and other photographic tricks. The lighting can be utilized in such a way that the artistic forming of the picture is accented in harmony with the idea involved. Another way in which flame arcs are used is for casting shadows in trick pictures and to represent prison scenes in the more artistic

manner of showing the shadows of the prison bars rather than the actual grim stolid fact.

It would not be expedient to describe in elaborate detail the many devices for rapidly moving the lights around in studios or the particular mechanical arrangement for carrying the lamps around on wheel cabinets or on trolleys or on ropes, etc. The actual installations of lighting are arranged in a great variety of ways, in some cases the overhead lighting is set up with the idea of permanently supplying the particular set. In other cases the overhead lighting is arranged so as to be easily moved by a trolley system from set to set. In the latter case the small weight of the flame lamps in proportion to their candlepower greatly reduces the cost of the moving system and also affords a better utilization for admitting overhead daylight if this is desired. For side lighting the flame lamps are mounted on wheel stands either separately or in powerful unit groups of 6 and 12. The typical Edison stage is shown in Fig. 19 and 20, which were most kindly supplied by the Edison Co. Here about 28 lamps of Aristo type are seen mounted in 4 rows of 7 each. These are arranged to be easily moved. One large stand lamp is shown in this picture, Fig. 18. *It is interesting to note that the resistance of the flame lamp can be mounted in a separate room so as to further reduce the heating which is remarkably small with the flame lamp.* In some studios a dozen Aristo lamps are mounted in a portable cabinet formed in sets of three rows of four each with the top row forward and the bottom row back away from the stage. The whole can be easily moved around the studio because mounted on wheels.

In Fig. 22 there is shown the overhead arrangement of flame arcs and mercury arcs used for lighting a boxing match at Madison Square Garden. (See Lighting Journal *4*, p. 78, Apr. 1916.) It is interesting to note that eight motion picture cameras were used simultaneously and that the entire room was so well lighted that brilliant illumination was obtained in every part of the large hall.

The use of flame arcs is carried out on an extensive scale in the Vitagraph motion picture studio located in Brooklyn, New York. Mr. Ross, master mechanic of the Vitagraph Co., was kind enough to furnish me data showing that the average number of flame lamps (20 amperes each lamp) used per set is twenty. In the Brooklyn studio alone, there are 225 flame arc lamps, hanging overhead, or in sets in stands or mounted so to be easily moved about in small carriages so as to eliminate shadows. In Fig. 20 there is shown a portion of one of the main studio rooms. In Fig. 21 is shown a setting of lighting arrangements received through the kindness of Miss Anita Stewart. In Fig. 24 and 25 are some interior studios that illustrate the use of multiple reflection to increase greatly efficiency and to give diffuse light.

Mr. Cecil B. DeMille, director of the Jesse L. Lasky Feature Play Co., wrote about three years ago, an article ("Motography 15, p. 240, Jan. 29, 1916") under the title "Lighting to a Photoplay is Like Music to Drama." He concludes that lighting effects as applied to motion pictures assume precisely the same value in the

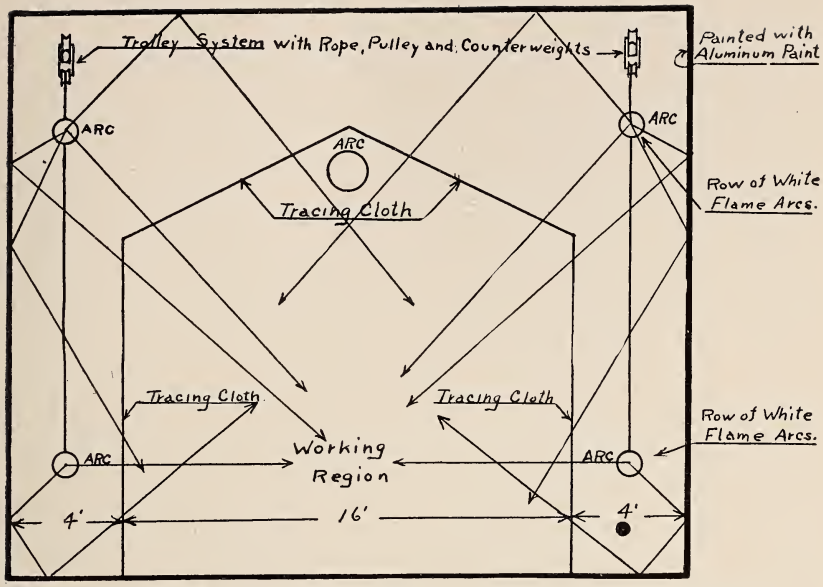


FIG. 24—Interior Room for High Efficiency Lighting by Multiple Reflection

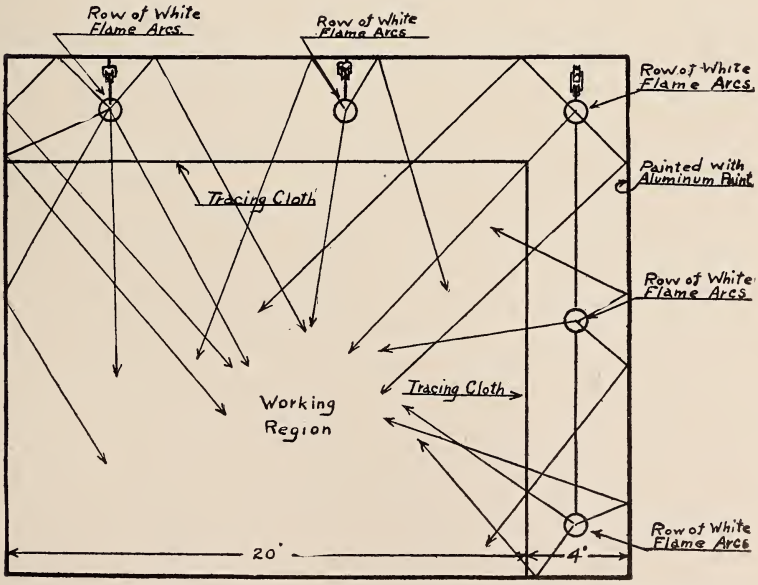


FIG. 25—Interior Room with Side and Top Diffuse Lighting with Flame Arcs

photo drama that music assumes in the spoken drama. He says "the theme of a picture should be carried in its photography." "The Cheat," representing unprincipled sinister Japanese characters, used abrupt bold light effects to definitely suggest the "clang" and smash of Japanese music.

In "Carmen," however, the Rembrandt idea was followed. The lighting and grouping of the characters in the soft shadows were all worked out in keeping with the school of that famous master. "Light effects are out of place in comedy; there you will notice our lighting is clear and brilliant corresponding to the faster light comedy and music, except in the melodramatic scenes where we carry our audience into thrills not only by the action of the artist, but by a change in the mode of our photography."

8. Looking to the Future

In conclusion, many new flame lamps have been invented and developed in the last year or two, and now varieties of flame carbons for special effects are available for a multitude of simple or complex artistic effects. However, only a small beginning has been made as to the artistic effects counting merely the minor factors of control such as direction of light, its diffusion, change of intensity and the power by proper color and environment to greatly aid the motion picture actor-artist. There is the subject of "catch-lights" in the eyes of the players that represent the reflection of the light sources. If the light sources are rectangular in shape, then the catch-lights will be rectangular or triangular, and with sharp curve points. The bad effect of not using round or oval light sources is easily appreciated. It is well recognized that curved lines convex to each other tend to give a sorrowful, depressed look. Curved lines concave to each other tend to give a pleasant, agreeable, smiling look. By attention to the shape of the diffusing screen for the light sources, it would seem possible to vary this element so as to be in harmony with the ideals of the play. All the recent motion picture photoplays of the best companies show the power of white flame arc lighting to give fine definition, splendid half tones, luminous shadows and favorably shaped "catch" lights.

In some portrait studios the light of the flame arc is thrown upon the ceiling (Fig. 26) or a reflecting screen, and in this way some very beautiful pictures have been photographed. The possibilities of indirect lighting with the flame arc have only been touched upon. By suitable lamp design, it seems practical not only to get more diffuse light, but also greater candlepower delivered to the working plane. Again in the matter of regulation, the shunt control (see Figs. 15 and 16) is one of the important future developments that will enable the artists to secure a wide variety of new effects.

The experiments with multiple trim lamps, Fig. 17, show how long life (long period between trims) can be secured for the flame arc.

On alternating current efficiency can be greatly increased with the flame arc by reactance control.

In the matter of studio lighting, the writer believes with Mr. Allison, that interior rooms lighted entirely by artificial light have

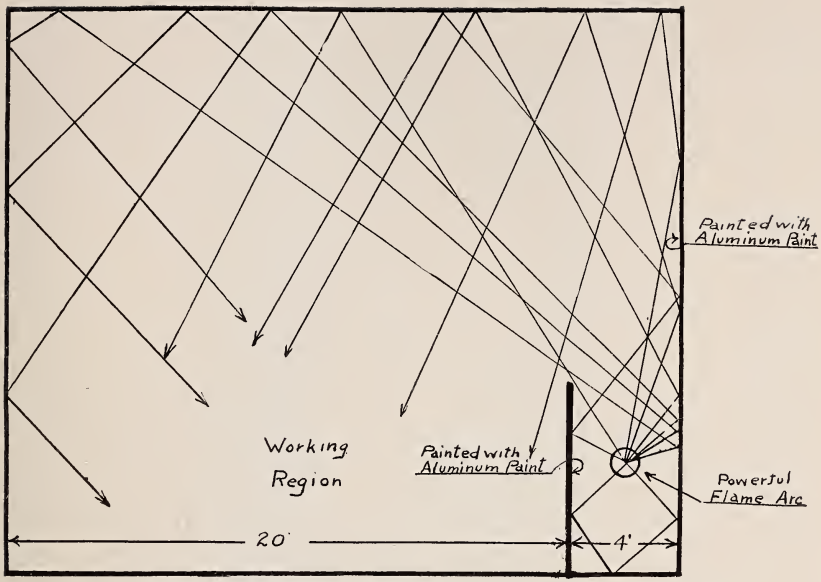


FIG. 26—Interior Room with Entirely Indirect Light with Flame Arcs

splendid advantages, because the lighting can then be entirely controlled by the artist, and the extremely hot atmosphere of sunlight glass studio is entirely done away, and a nice cool comfortable studio can be maintained throughout the year. The director can then obtain all diffuse light, all direct light, or any proportion and direction of diffused and direct light under perfect control, and old Kiny Sol with his changing position, will be entirely unnecessary for all interior scenes. In conclusion this article has pointed out mang new developments, and has indicated the promise of many others in development of different colored flame carbons, and a great variety of motion picture flame lamps.

Finally, it is my privilege to express my great indebtedness to many who have so kindly contributed time, suggestions, and photographs to this paper. I am indebted to Mr. P. P. Bethea for aid in many long experiments on the flame arc, to Mr. A. Broggini for assistance in securing many of the photographs, to Mr. Ross, master mechanic of Vitagraph, and Miss Anita Stewart for pictures from the Vitagraph Co., to the Edison Co., and to Mr. Bechwith of the Reserve Photoplay Co. for pictures, to Mr. Max Mayer (of Wohl & Co.) for friendly suggestions, to Mr. Allison, Mr. J. E. Brubec, and to many others who have so materially contributed to the value of this paper.

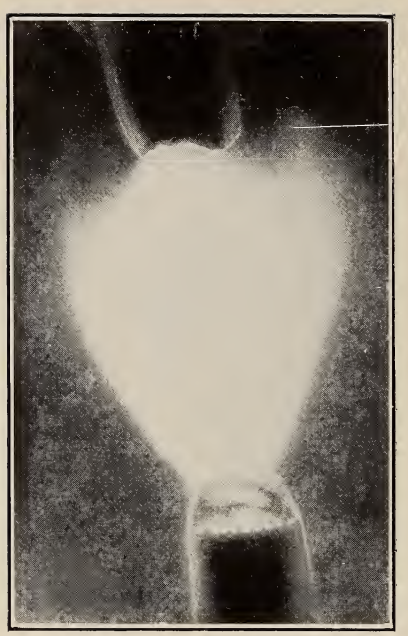


Fig. 27—Photograph of a White Flame Arc

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PHOTOGRAPHIC EFFICIENCY AT LIKE CANDLEPOWER

Source	Ordinary Plate	Artho. Plate	Panchro-matic
Sunlight	100	100	100
Skylight	181	155	130
White flame light	287	234	215
Clear bulb gas filled	64	68	76
Blue bulb gas filled	108	99	106
Mercury vapor	316	354	273
Mercury arc nultra glass	218	195	165

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32. Kenneth Macgowan, New Republic, vol. 12, p. 188, Sept. 15, 1917.

Formerly the motion picture studios gave the effect of flat, almost footlight scenes but the new effect—an American made device—introduce natural lighting from windows, doorways and lamps. This enables sharp staring shadows to be produced in scenes of terror or soft luminous shadows to stimulate the pleasing evening lighting. Again the new lighting can be so arranged to concentrate on the acting and avoid the effect of camera consciousness which is introduced by the old camera for concentrating the attention on the actors. He says that art in the motion pictures arises chiefly from sequence of pictorial impressions but more especially from lighting atmosphere.

SOME PHASES OF THE OPTICAL SYSTEM OF THE PROJECTOR

By F. H. Richardson

For the past twelve years we have been engaged in the study of the practical optics as applied to the motion picture projector. Through observation, we discovered that the projection lens of our projector did not pick up the entire light beam, whereas others that had lenses of equal diameter did pick up the entire light beam.

Some projectionists and theorists claimed that the beam beyond the aperture plate converged, while others, like myself, claimed that the beam diverged. We were both right; the difference being that the principal image of the arc crater was in the first case somewhere in or near the center of the projection lens, whereas, in all of my experience, the principal focus was at the aperture plate.

In order to obtain some data on this question, we employed John Griffith, Ansonia, Conn., to assist and to him the industry owes much for the very excellent work he has done in giving to it the first really workable data existent for enabling the projectionist to handle his projector optical train intelligently.

Briefly stated, the experiments which we undertook were chiefly to demonstrate that the beam from the condenser diverged between the aperture plate and projection lens when the arc crater was imaged at the aperture and this divergence was in proportion to the diameter of the condenser and inversely proportional to its distance from the aperture.

In Fig. 1 this theory is set forth diagrammatically. The whole condenser ray is indicated by the upper and lower converging dotted lines. Line B, drawn from the upper edge of the condenser to the lower edge of the aperture opening, and line A drawn from the lower edge of the condenser to the upper edge of the aperture opening, if continued beyond the aperture, marks the confines and shows the shape of the ray between the aperture and projection lens. Granting Fig. 1 to correctly illustrate what actually does take place, it is then readily understood that, condenser diameter remaining constant, the further the condenser is located away from the aperture the less will be the divergence of the beam between the aperture and the projection lens; conversely, the closer the lens to the aperture the greater will be the divergence, the exact effect of increased condenser distance being illustrated in Fig. 2.

In Fig. 2 the upper drawing illustrates the conventional method of showing the optical train of the projector. Insofar as it applies to arc light projection in practice, it is entirely wrong. The center drawing shows the effect were the condenser located 9⅜ inches from the aperture, with point of greatest concentration at the aperture. At 2 inches B. F. the projection lens would have to be 1.75″ in diameter to accommodate the entire ray. At 5.5″ B. F. it would have to be 3.75″ in diameter. The lower drawing shows the effect with the condenser at 15″ from the aperture, while the

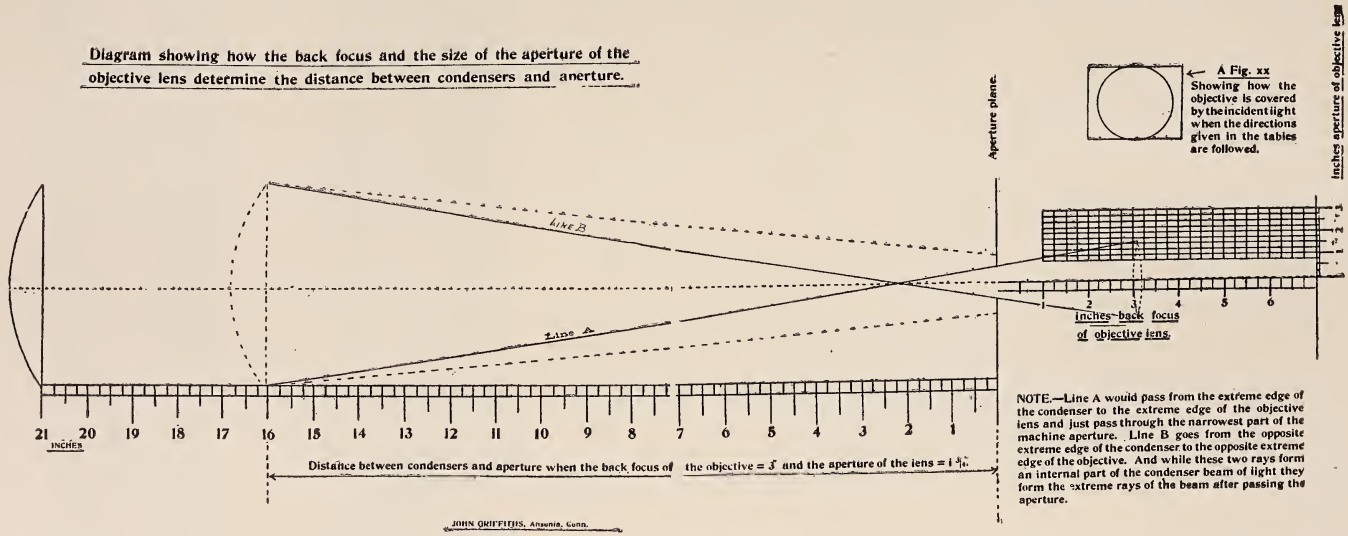


Diagram showing how the back focus and the size of the aperture of the objective lens determine the distance between condensers and anerture.
Aperture plane.
A Fig. xx
Showing how the objective is covered by the incident light when the directions given in the tables are followed.
Inches aperture of objective lens
LINE B
LINE A
2 3 4 5 6
Inches-back focus of objective lens.
21 20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
INCHES
Distance between condensers and aperture when the back focus of the objective = 3" and the aperture of the lens = 1 3/4".
NOTE.—Line A would pass from the extreme edge of the condenser to the extreme edge of the objective lens and just pass through the narrowest part of the machine aperture. Line B goes from the opposite extreme edge of the condenser to the opposite extreme edge of the objective. And while these two rays form an internal part of the condenser beam of light they form the extreme rays of the beam after passing the aperture.
JOHN GRIFFITHS, Ansonia, Conn.

FIG. I

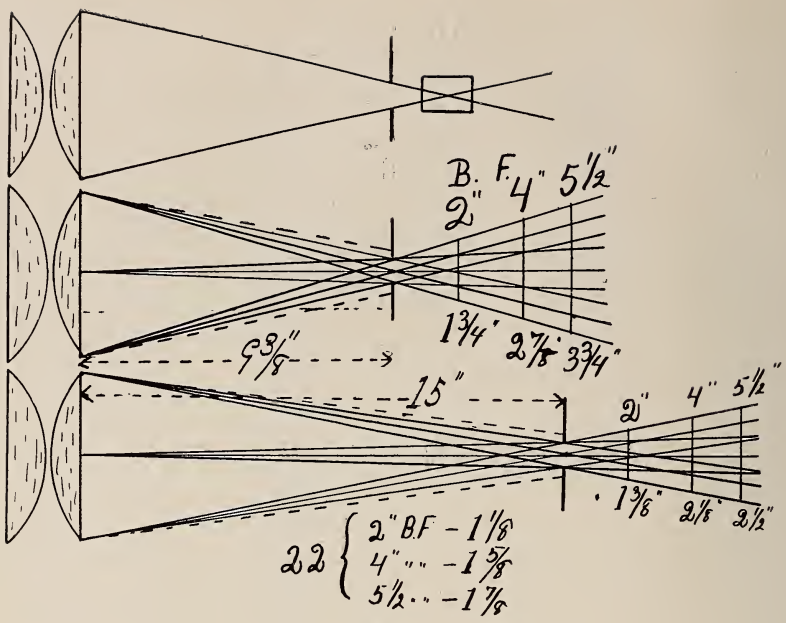


Fig. 2

figures below show the effect with the condenser at 22″ from the aperture.

Fig. 3 shows us the condenser covered by a metal plate in which two small holes are drilled, just inside opposite diameters of the condenser lens. The plate rests against the front surface of the

Fig. 3

Fig. 4

front condenser lens. A standard motion picture projector aperture plate is mounted on a metal plate and is placed at the crossing point of the rays, hence at the point of greatest concentration of the condenser beam. This experiment shows that, with the aperture located at or ahead of the point of greatest concentration of the condenser beam, the beam does diverge beyond the aperture.

In Fig. 4 we have still further proof of the divergence of the beam under the conditions named. Fig. 4 is the same as Fig. 3, except that the metal plate has been removed and the projection lens set in place.

We have thus shown that the ray does diverge beyond the aperture when the aperture is at or ahead of the point of greatest concentration of the condenser beam, and that the divergence is in exact proportion to the diameter of the condenser and inversely proportional to its distance from the aperture.

There is, however, a theory still tenaciously adhered to by some that the point of greatest concentration (often incorrectly called the crater image—incorrectly, because, due to the fact that the crater is neither a flat surface or parallel to the lens, it, the image, actually is in focus in its various parts through a considerable length of the condenser beam) of the condenser beam should be advanced to a point between the factors of the projection lens, as is the correct practice in stereopticon projection. Those who have given the matter exhaustive study, from the practical as well as the

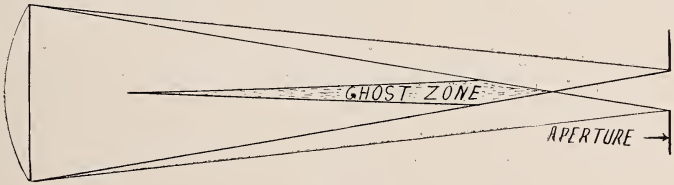


Fig. 5

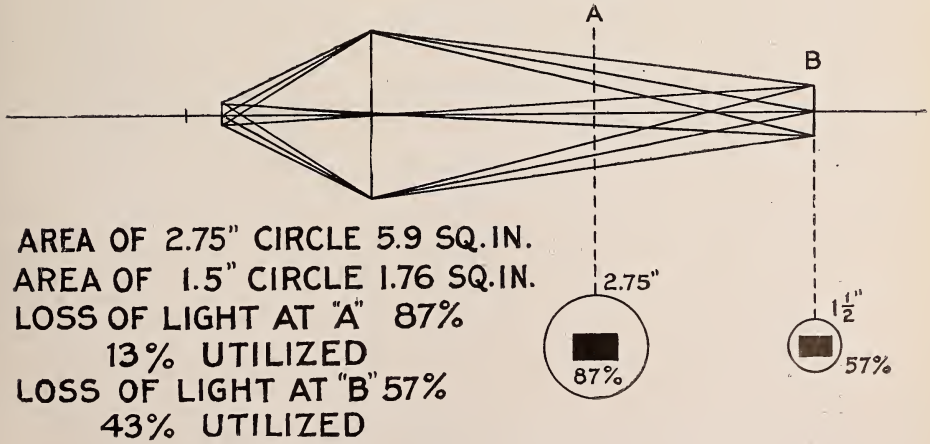


Fig. 6

theoretical point of view, however, realize that stereopticon projection, in which the object to be projected lies at the front plane of the condenser, and motion picture projection, in which the object to be projected lies a considerable distance from this point, presents two very different problems. In theoretical optics it may be perfectly right to locate the point of greatest concentration within the projection lens, but any practical projectionist will tell us that in arc light projection of motion pictures it is not satisfactory. There are several reasons for this, two of which I will name: First, it is not practical because of the fact that the advancement of the point of greatest concentration to any considerable distance beyond the aperture brings the aperture into the "ghost zone" (the condenser light ray being, as a whole, made up somewhat as shown in Fig. 5), which sets up a ghost in the center of the screen. This alone is quite sufficient to prevent the advancement of the point of greatest concentration much beyond the aperture. Second, as will be seen by a glance at Fig. 6, the waste of light at the "spot" incident to advancement of the point of greatest concentration ahead of the aperture is very great and increasingly so as the advancement increases. This, while not making the advancement of the point of greatest concentration to the projection lens impossible, does make it impractical on the score of cost.

Before leaving this phase of the subject let me remark that whatever theorists may contend, the fact is that practical projectionists find it impossible to get desired results in arc light projection with the point of greatest concentration advanced appreciably beyond the aperture.

The before described experiments proved to us two things conclusively, viz.: (a) With arc light projection of motion pictures and the optical train adjusted according to universally accepted practice, the light beam does diverge beyond the aperture in exact proportion to the diameter of condenser and inversely proportional to its distance from the aperture, as before set forth. (b) If the divergence of the ray be such that its diameter is greater than the diameter of the opening of the projection lens at the plane of the back focus of the projection lens, then the practical effect is to reduce the diameter of the condenser, and thus waste light, which, of course, means wasted electrical energy and coal. And since the diameter of projection lenses working with a brilliant source of illumination is limited by the fact that it must work in conjunction with the revolving shutter of the projector, this loss becomes a very serious matter where long focal length projection lenses are used. The amount of reduction of condenser diameter may be determined, in any given case, by extending lines B and A, Fig. 1, to meet the edges of the opening of the projection lens at its point of back focus.

Based on knowledge obtained during the aforenamed experiments, supplemented by exhaustive study of the whole proposition, John Griffiths proceeded to compile for us a series of lens tables and charts, finally culminating in the one recently published and shown in Figs. 7A and 7B.

These tables and charts have as their basis the minimum distance it is possible to locate a crater of given amperage, under normal,

average working conditions, to a condenser lens without undue lens breakage; in other words on the practical limit of heat a condenser lens will stand under normal working conditions. They also are calculated on the equivalent focus of the condenser combinations named when the factors are so placed that their apexes (plano con-

FOR MENISCUS BI-CONVEX CONDENSERS								↑	FOR PLANO CONVEX CONDENSERS							
DIAM. OF OBJECTIVE				CONDENSERS		AMPERAGE		DISTANCE TO APERTURE	AMPERAGE		CONDENSERS		DIAM. OF OBJECTIVE			
3" B.F.	4" B.F.	5" B.F.	6" B.F.	ARC	FRONT						ARC	FRONT	3" B.F.	4" B.F.	5" B.F.	6" B.F.
								16"	60	D.C.	6½	7½	1.76	2.	2.3	2.56
									55	D.C.	6½	7½				
								17"	50	D.C.	6½	7½	1.66	1.9	2.2	2.42
1.65	1.9	2.15	2.4	6½	9½	60	D.C.		45	D.C.	6½	6½				
				6½	9½	55	D.C.	18"								
									40	D.C.	6½	6½	1.56	1.84	2.1	2.3
1.6	1.8	2.1	2.25	6½	8½	50	D.C.	19"	60	A.C.						
				6½	8½	45	D.C.		35	D.C.	6½	6½				
								20"								
1.54	1.75	2.	2.14	6½	8½	40	D.C.	21"	30	D.C.	6½	6½	1.5	1.75	1.94	2.16
						60	A.C.		40	A.C.						
				6½	8½	35	D.C.	22"	25	D.C.	5½	6½				
								23"								
1.45	1.65	1.85	2.	6½	7½	30	D.C.									
						40	A.C.	24"								
								25"								
				6½	7½	25	D.C.									
								26"								

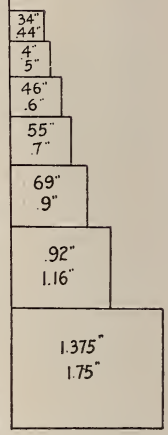
PROJECTIONIST'S OPTICAL CHART

THE AMPERAGE IN USE INDICATES THE FOCAL LENGTH OF CONDENSERS THEIR DISTANCE FROM THE APERTURE AND THE DIAMETER OF THE OBJECTIVE LENS THAT SHOULD BE USED.

Lens Chart No. 1, © 1918 by Chalmers Publishing Company

vex) are not to exceed $\frac{1}{16}''$ apart. Further spacing alters the E.F. of the combination sufficiently to seriously affect results. It must also be remarked that, while these charts and tables have already amply proven their value, there is and always will be some slight variation in application because of the fact that condenser lenses are

PROJECTION LENS E.F.	DISTANCE BETWEEN CONDENSERS & APERTURE INCHES	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
3"	DISTANCE APERTURE TO CONDENSER IMAGE									7"			6.75			6.6			6.5			6.4			6.3		
	HEIGHT OF IMAGE									.92			.69			.55			.46			.4			.34		
	WIDTH OF IMAGE									1.16			.9			.7						.5					
3½"	DISTANCE										8	.16			7.9			7.7				7.5					
	HEIGHT										.92				.69			.55				.46					
	WIDTH										1.16				.9			.7				.6					
4"	DISTANCE												9.3				.9				8.8						
	HEIGHT												.92				.69				.55						
	WIDTH												1.16				.9				.7						
4½"	DISTANCE													10.5					10.1								
	HEIGHT													.92					.69								
	WIDTH													1.16					.9								
5"	DISTANCE										12.5					11.6					11.25						.11
	HEIGHT										1.375					.92					.69						.55
	WIDTH										1.75					1.16					.9						7
5½"	DISTANCE											13.7						12.8					12.4				.12
	HEIGHT											1.375						.92					.69				.55
	WIDTH											1.75						1.16					.9				.7
6"	DISTANCE												15						14						13.5		
	HEIGHT												1.375						.92						.69		
	WIDTH												1.75						1.16						.9		
6½"	DISTANCE													16.2							15.1						14.7
	HEIGHT													1.375							.92						.69
	WIDTH													1.75							1.16						.9
7"	DISTANCE														17.5							16.3					16
	HEIGHT														1.375							.92					.7
	WIDTH														1.75							1.16					1"



Lens Chart No. 2, © 1918 by Chalmers Publishing Company

Figs. 7A and 7B

not accurate in focal length. A 7.5 in. plano convex lens, for instance, is apt to be almost anything between 7.25 in. and 7.75 in. focal length. Also the mechanical limitations of even the most modern projectors render the application of lens tables impossible for all amperages until changes have been made in the machine. Notwithstanding these difficulties, however, the charts and tables have proven of great value to projectionists, and the industry is deeply indebted to Mr. Griffith for the work he has done along these lines.

Knowing that the beam diverged between the aperture and objective lens when the crater was imaged at the aperture, we were anxious to ascertain to what extent light was lost when the diameter of the objective was less than the diameter of the beam.

In order to obtain this data, we requested the National Lamp Works Laboratories, Nela Park, Cleveland, Ohio, to make measurements of the light flux at different points across the beam, at different distances beyond aperture and with the condenser at certain designated distances from the aperture.

In order to obtain check data, we requested the Westinghouse Lamp Company Laboratories, Bloomfield, N. J., to make similar

measurements. Both these companies were good enough to accede to our request and made the desired measurements. We desire to tender our most sincere thanks to the National Lamp Works and the Westinghouse Lamp Company for their aid in this matter.

These measurements have proven that a huge loss of light may occur through failure to properly design projection lenses, particularly those of long focal length, with maximum diameter and *short back focus*. Lens manufacturers in our opinion, have heretofore not given this hugely important matter anything like sufficient attention. In fact, aside from increase of diameter nothing at all, so far as we know, has been done by the leading lens manufacturers to design lenses to fit the obvious need, though one lens made by an obscure manufacturer has pointed the way, and has amply proven its worth. Increase of lens diameter is not sufficient to meet the situation except in lenses of short or medium focal length. Lens diameter is necessarily limited, due to the fact that projection lenses must work in conjunction with a revolving shutter. This is particularly true where a light source of great brilliancy is used.

In our opinion there is urgent need for a re-designing of projection lenses, particularly those of long focal length. Personally we believe this can only be taken care of by designing lenses which shall in no case have a back focus greater than perhaps two inches, though the exact figure we would not care to state positively without further study on that particular matter. If this can only be done by means of a three-combination lens, then we believe a three-combination lens is the thing needed.

The following results were arrived at by the National Lamp Company laboratories after an exhaustive series of measurements of the projector light beam between the aperture and the projection lens. The same measurements by the Westinghouse laboratories gave essentially identical results. We may therefore confidently say they are correct.

* * *

The following is a summary of data supplied by the National Lamp Company.

"*Object:* To determine the relative intensities of various points in various planes across the light beam on the projection lens side of the aperture plate.

Description: The optical system was mounted as indicated in Fig. 8, upon which appears the dimensions used for the six settings. The condensers were ordinary 6.5 in. and 7.5 in. foci plano-convex, 4.5 in. in diameter. The light source consisted of a small piece of opal glass over which was mounted a metal plate with a 0.5 in. diameter opening. This opening was illuminated by a Mazda projection lamp which gave us a light source without variation in brilliancy, and one which for the purpose gave practically the same effect obtained from the crater of an electric arc. Fig. 9 shows the mounting of the Weber photometer. In Fig. 8 the radiating rows of round dots are quarter

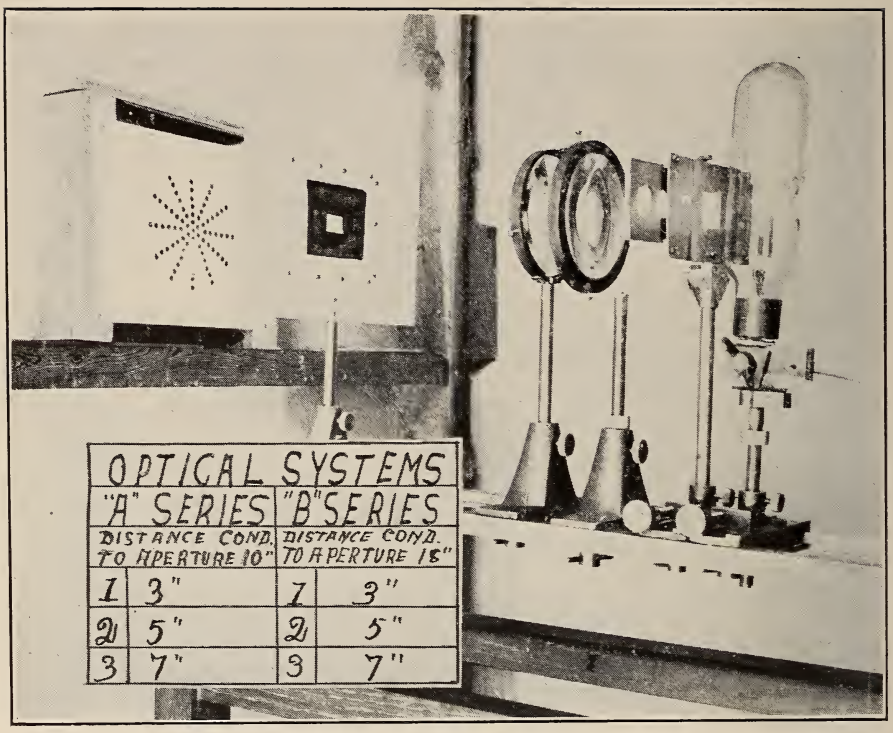


Fig. 8

inch holes in the screen, through which the measurements were made. Their opposite side is seen in Fig. 9. This screen was laid out in several "zones." The first, or center zone is a 3/8 in.

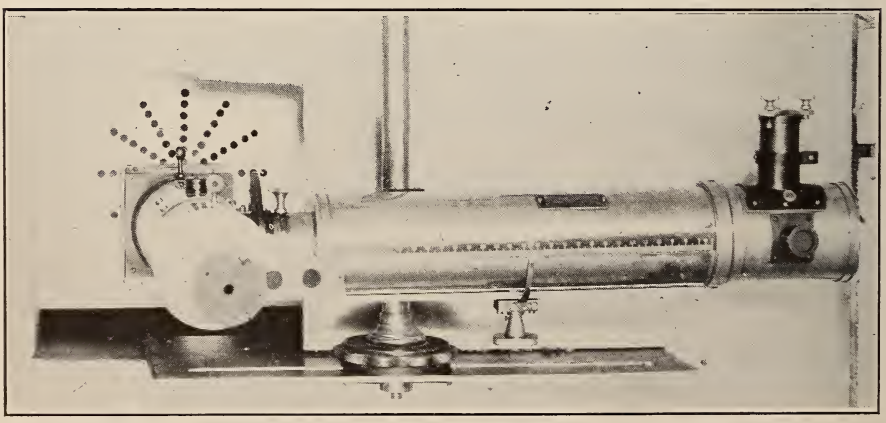


Fig. 9

circle, and each succeeding zone is ⅜ in. wide. It will be seen that this arrangement allowed of a remarkably complete measurement of the whole area of the light beam, and a very exact plotting of these measurements afterward.

Results: Following will be found tabulated results which were obtained from the test. For each test in each series the spot obtained is shown full size, and on it are indicated the zones, with the segments in the center of which observations were taken. Figures in these segments represent foot candles obtained by measurement. The chart contained in Fig. 8 shows the relation of condenser and aperture. In "Series A" the aperture was located 10 in. from the condenser. In "Series B" the distance was 18 in. Three series of measurements were made with each of these distances, viz.: at three, five and seven inches from the aperture.

Fig. 10 shows No. 1, 2 and 3 of the measurements taken in the A series (condenser 10″ from aperture) and Fig. 11 shows No. 1, 2 and 3 of the measurements taken in the B series (condenser 18″ from aperture). With each figure is given, in tabular form the calculated results.

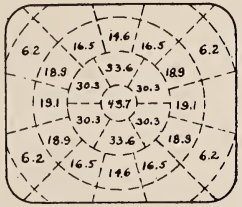
Discussion: In the first place, we have shown that with the source imaged at the aperture, the beam emerging from the aperture is diverging, the amount of divergence being proportional to the diameter of the condenser and inversely proportional to its distance from the aperture. We have also shown that a considerable portion of the light lies outside of the parallel beam from the aperture, meaning by "parallel beam" a beam of uniform cross-section equal to that of the aperture and parallel throughout its length to the optical axis. The amount of light lying outside this parallel beam, considering the area of the beam as equal to the area of the first two zones, can be readily seen from a study of Table 1.

TABLE NO. 1

Light Outside of a Parallel Beam

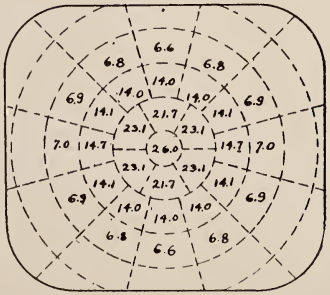
Series "A" Condenser 10 in. from aperture	Series "B" Condenser 18 in. from aperture
3 in. from aperture—60%	3 in. from aperture—40%
5 in. from aperture—72%	5 in. from aperture—47%
7 in. from aperture—76%	7 in. from aperture—57%

To get at the real significance of the above figures we must consider the area of the beam which would be covered by the opening in a projection lens, which, for the purpose of this paper, we will call 2 in. The area of the opening of the lens then would be approximately equal to the area of the first three zones, as shown in Figs. 10 and 11. Assuming, then, that the lenses used would have a back focus equal to the distances from the aperture plate used in this investigation (3, 5 and 7 in.), we find there is a large proportion of the light which would not be used by the lens, and that the quantity



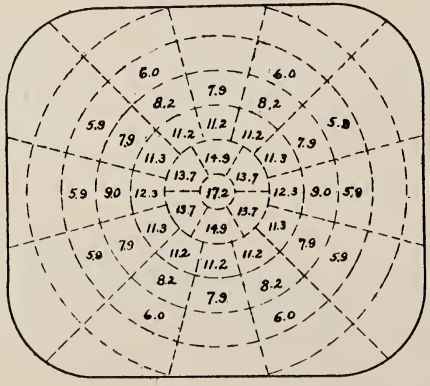
Zone	Area sq.ft.	Avg F.C.	Lumens	% Total
1	.0077	43.7	.3.4	5.8
2	.062	31.4	1.95	33.6
3	.123	17.4	2.14	36.6
4	.113	6.2	1.40	24.0
remaining zones				
		Total	5.83	

Fig. 3.



Zone	Area	Avg FC	Lumens	% Total
1	.0077	26.0	.200	3.4
2	.062	22.0	1.40	24.0
3	.123	14.2	1.75	30.0
4	.183	6.83	1.25	21.5
remaining zones			1.26	21.0
		Total	5.83	

Fig. 4

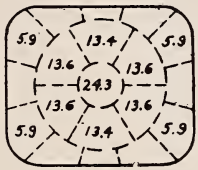


Zone	Area	Avg F.C	Lumens	% Total
1	.0077	17.2	.13	2.3
2	.062	14.1	.88	15.1
3	.123	11.4	1.40	24.0
4	.183	8.4	1.54	26.4
5	.245	5.9	1.47	25.2
remaining zones			.41	7.0
		Total	5.83	

Fig. 5.

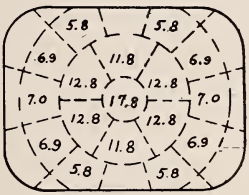
FIG 10

increases with (a) length of back focus and (b) nearness of condenser to aperture.



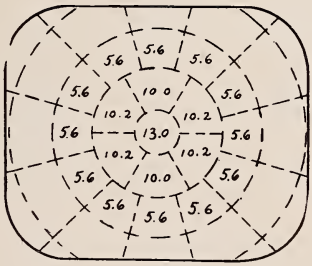
Zone	Area	Avg. F.C.	Lumens	% Total
1	0077	24.3	19	10 8
2	062	13.5	.86	49.2
3			.70	40.0
		Total	1.75	

Fig 6.



Zone	Area	Avg. F.C.	Lumens	% Total
1	.0077	17.8	.14	8.6
2	.062	12.5	.78	44.6
3	.112	6.9	.77	44.0
remaining zones			.06	3.4
		Total	1 75	

Fig. 7.



Zone	Area	Avg. F.C.	Lumens	% Total
1	0077	13.0	.10	5.7
2	.062	10.1	.63	36 0
3	.123	5 8	.71	40.6
remaining zones			.31	17.7
		Total	1.75	

Fig. 8

FIG. 11

Table No. 2

Light Outside a 2 in. Circle

Series "A" Condenser 10 in. from aperture	Series "B" Condenser 18 in. from aperture
3 in. from aperture—24%	3 in. from aperture— 0
5 in. from aperture—43%	5 in. from aperture— 3%
7 in. from aperture—49%	7 in. from aperture—18%

Table No. 2 gives the percentage of light outside the first three zones, or, in other words, outside a 2 in. circle.

Conclusion: It then is apparent that in choosing a projection lens to fit given conditions, attention must be paid to the condenser and its distance from the aperture, as well as to throw and size of picture.

For a given throw and picture size, the diameter of the projection lens which would utilize the greatest percentage of the light passing through the film would depend, to a great extent, upon the position of the condenser. With the condenser fairly well forward, the required lens would necessarily have a much larger diameter than if the condenser be located pretty far back, with consequent less divergence of the beam, but it must be remembered that the distance of condenser from aperture is automatically fixed by considerations beyond control of the projectionist.

Fig. 7 shows the location of the condenser to be variable, hence there is only one practical method left us for overcoming the tremendous loss of light incident upon using long focal length projection lenses, and that is the shortening of their back focus. This is particularly true where high amperage is used, since high amperage acts automatically to bring the condenser nearer the aperture, thus increasing the divergence.

In explanation of the large percentage of light lying outside the three central zones (2 in. circle), I would respectfully call your attention to the fact that, whereas the light flux within the central zones has much higher value per unit of area, the area of the outer zones is immensely greater than that of the central zones, which acts to even things up.

Gentlemen, in view of the fact that distance of condenser from aperture is automatically fixed by amperage, which acts to compel the use of a widely diverging beam beyond the aperture where heavy amperage is used, I am obliged to reiterate my recommendation that projection lenses be re-designed in such a way that no lens will have a back focus greater than 2 in., or at most 2½ in.

Discussion by Dr. Kellner

I had planned to speak myself to-day on the condenser subject but upon seeing Mr. Richardson's and Mr. Burrows' able and elaborate paper I decided to confine myself to a few remarks.

On account of the spherical aberration in the ordinary condenser the rays coming from the source and passing through its marginal zone intersect the optical axis much nearer the aperture plate, and under a much greater angle than the rays passing through the center of the condenser. If the diameter of the lens is not large enough it happens that some of the rays coming through the marginal zone of the condenser are not intercepted by the lens and, therefore, lost for the illumination on the screen. This is illustrated in the first figure.

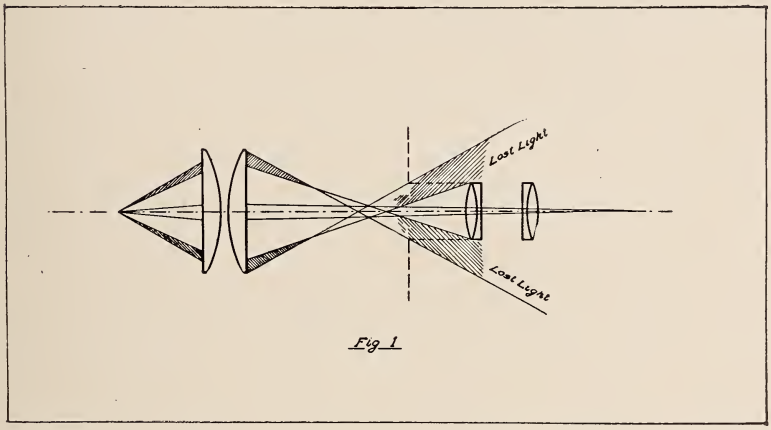


Fig 1

Such loss may be avoided in two ways:

1st. By making the aperture of the lens large enough to collect those rays or by keeping the aperture the same as before and bringing the rear combination of the lens so close to the aperture plate that the lens intercepts the rays otherwise lost, in other words by reducing the working distance (back focus in Mr. Richardson's paper).

2d. By reducing the spherical aberration of the condenser so that rays coming through the margin of the condenser pass through the lens.

The first remedy is not very inviting to the lens computer nor to the lens maker. The greater the aperture of the lens in proportion to its equivalent focal length the more difficult it is to correct the aberration and the more difficult it is to produce the lens and also the more sensitive such lens is to small variations in the adjustment of the machine.

A lens with shorter working distance can be constructed by adding a third combination. This has the disadvantage of additional loss of light by reflection and absorption in the added member, amounting to 10% which will have to be subtracted from the amount gained by the shorter working distance.

The working distance may also be shortened in a two combination projection lens by increasing the distance between the combinations. This, however, has also difficulties of its own.

It seems to me more logical to leave the projection lens alone and remedy the evil by using a condenser that sends through the projection objective all the light which it collects from the source. For this purpose we must reduce the spherical aberration of the condenser to such an extent that the rays coming through the margin of the condenser intersect the optical axis near enough to the objective to be intercepted by the latter and thus contribute to the illumination on the screen. This is illustrated by the dotted lines in Fig. 2. The full lines show the path of the rays through the central and marginal zone of a fully corrected condenser.

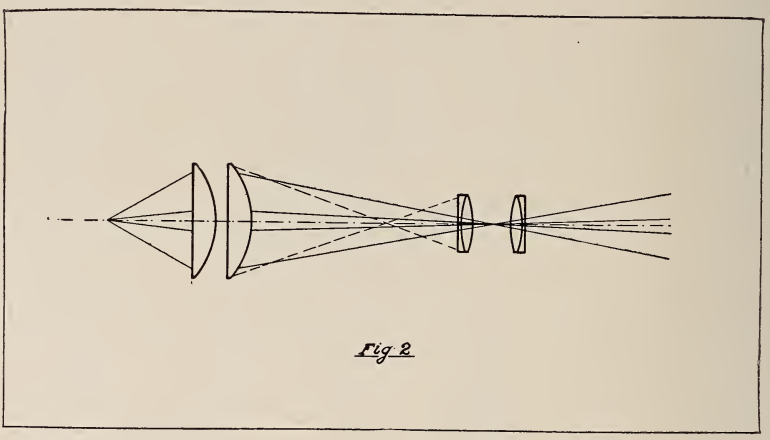


Fig 2

I have here a model of a projection apparatus which shows very nicely the condition under discussion. These are interchangeable condenser systems consisting of the same number of lenses and having the same equivalent focus and aperture. One of these condensers is spherically corrected and produces a small distinct image of the source, while the non-corrected one shows at the same distance a diffused image of the source surrounded by a broad circular halo. The outer zone of this halo which falls outside of the circumference of the projection lens is of course lost.

It is evident that with the spherically corrected condenser a lens of very much smaller diameter would be sufficient to give the same illumination on the screen as the large lens in combination with a non-corrected condenser.

I must confess that I cannot quite reconcile the figures of loss as given by Mr. Richardson and Mr. Burrows with an experience I had several years ago.

A short working distance lens was submitted to me, built especially from the view point of meeting the criticism set forth in Mr.

Richardson's paper. It was claimed that this lens showed an increase of illumination of about 100% on the screen. A comparison between this lens and a lens of the ordinary type was made in the following way:

In the booth of one of the theaters of Rochester two machines of the same make and type were placed side by side and run under as nearly as possible the same conditions using the same size carbons, keeping the current the same, etc. The fields projected by the lenses in competition could be compared side by side on the screen. Under similar conditions the new lens was supposed to show a 100% superiority in the illumination. The originator of the short working distance lens, himself, adjusted the machines, as well as for another comparison, the operator of the theatre and afterwards a third impartial person. It goes without saying that the objectives also were changed from one machine to another. The judges sat in the orchestra too far away from the booth to know what was going on in the booth. The result was that no one could definitely tell which lens was illuminating the one field or the other. There were slight differences in the illumination but they were caused evidently by accidental conditions and did not at all depend upon the lenses. The experiment was repeated a number of times with no differing results. This test is, of course, very coarse when compared with the methods used by Mr. Richardson and Mr. Burrows, but seemed at that time sufficient to convince me that the amount of illumination possibly gained was not worth while the additional complication of the projection lens. As soon as I have a chance I shall repeat such test and see whether I cannot make Mr. Richardson's conclusions agree with a practical test in the theater.

CONTRIBUTED DISCUSSION BY DR. STORY

If you will allow an outsider to add to this discussion, I should like to suggest that as in so many arguments one difference between the paper and the opposition it mentions is simply a matter of terms. In the paper the word "beam" and "ray" are both used to denote the complete cone of light emerging from the condenser. Now in optics "ray" is used as a convenient expression for a light path of infinitely small cross section. A ray accordingly can never diverge any more than it can converge. To the theorist then to speak of the ray diverging from the point of maximum concentration is a misnomer.

On the other hand, the condition for the convergence of the entire beam issuing from the condenser is that the image of the source shall be smaller than the condenser or, in the case of a condenser having spherical aberration, not much larger. Or that where

$$D_s < \frac{D_c\,(d_s - F_c)}{F_c}$$

D_s is the diameter of the source, d_s the distance from the optical center of the condenser to the source, D_c the diameter of the condenser, and F_c its focal length. This condition is invariably met

with in practice. Beyond the point of maximum concentration this beam does diverge as the paper shows.

If the condenser has spherical aberration the rays through the center will image at, or as we say, "converge to," a point beyond the point of maximum concentration. At this imaging point of the central rays the rays through the outer part of the condenser have already converged to an image and now diverging form the boundary of the diverging beam. Thus we see that the beam is diverging beyond the point of maximum concentration, as the name of this point indicates, some of the rays are still converging.

This misunderstanding simply illustrates the necessity already pointed out in this meeting of care being exercised to use terms taken over from the older branches of optics in their previous meaning where this is possible.

The question as to whether the point of maximum concentration should be at the aperture plate or at the objective is a very different matter. To consider this we must advance but one theory and that amply proved experimentally. That theory is that the maximum light at any point from any source of uniform brilliancy through any opening has been obtained when the entire apparent area of that opening is covered by the source of its image. This, of course, leaves out of account losses due to the reflection from lens and mirror surfaces and absorption in their materials. This means that if at any point beyond the aperture plate every point of the film has a bright spot of the condenser behind it, at this point we have as much light through the film as is possible to obtain with a source of this intrinsic brilliancy. If this is true for every point on the objective lens, we are supplying to this lens all the light it can use, for each of its points has the maximum light available. If there are any points alongside the objective for which this condition obtains, then the lens is not using all the light the rest of the system is offering it. Let us be sure to remember, however, that the condition is that behind all points of the film there shall be an illuminated area.

If we consider a vertical section through a diagonal of the aperture plate and the center of the objective, and if we draw lines from the top and bottom of the objective opening to the bottom and top of the aperture respectively, and extend these lines in both directions, they obviously indicate the cone that must be filled with light in order to have our conditions of maximum brilliancy satisfied, and it does not in the least matter from the standpoint of quality of light through the objective how far from the aperture plate the source or condenser is placed. The only requirement is that the base of this cone as seen from all points of the objective shall have at every point the brilliancy of the source. If we could use a source large enough to cover this base at any point beyond the aperture, no combination of mirrors and lenses with this source would give us one iota more light on the screen. By the use of a condenser, however, we can cut down the necessary size of our source and in so doing decrease our power consumption.

The object of the condenser is then simply to make the source seem larger, so large in fact for best illumination that it covers the

entire base of this cone and by just as much as this magnification of the source fails to cover the cone by that same proportion does our light through the objective and therefore on the screen fall below the amount possible with the illuminant aperture and objective used. Now to cover this cone we must have certain conditions fulfilled. In the first place, it is obvious the condenser must be as large as the cone at the point at which the condenser is placed, and that any area of the condenser outside this cone is entirely useless. In the second place, and here comes the point in the paper to which all this serves but as preamble, the entire area of the condenser seen through the aperture from every point of the objective opening must appear illuminated, that is, every straight line on which points of the objective and points of the aperture both lie is an actual path of light.

If we consider a corrected condenser it is easily seen that this condition is fulfilled, if, and only if, some section of the cone in front of the aperture or beyond the objective shall be entirely covered by an image of the source. Between the aperture and objective the image must cover the area indicated by lines diagonal on our section from the top and bottom of the objective opening to the top and bottom of the aperture opening respectively. We see then that any position from the condenser to the screen, of the image of the source by the condenser is capable of giving the maximum light possible with the objective, provided only the cone is completely filled. For the best position, therefore, of the image we must look to some other factor than simply the maximum possible illumination, always keeping in mind, however, the two requirements already found.

The natural direction to look is toward efficiency. At which one of all these image positions can we get this maximum quantity of light through the objective with the least power consumption—that is, the smallest area to be illuminated to the intrinsic brilliancy determined by the nature of the illuminant? We see at once that we shall need a smaller area of source if we so choose the focal length of our condenser that the image will fall at the aperture plate than at any position in front of this with a given minimum distance between source and condenser—generally determined by practical limitations of temperature. For positions of the image beyond the aperture plate we easily see that if D_o is the effective diameter of the objective, F_o its equivalent focus, D_a the diameter (or diagonal) of the aperture and D_A its distance from the optical center of the condenser, the necessary source area is still a minimum with the image at the aperture plate unless

$$D_o < \left(1 + \frac{F_o}{d_A}\right) D_A$$

in which case we can use a smaller source with it focused in the objective than would be necessary for maximum illumination if the image were focused on the aperture. This condition is usually fulfilled in lantern slide but not in motion picture projection.

As for the distance from the condenser to the aperture it may be selected at will, subject of course to the condition that the

condenser must cover the entire cone, or the smallest diameter allowable is

$$D_c = D_A + D_A \left(\frac{D_o + D_A}{F_o} \right)$$

Then with everything else kept constant we can get as large a D_A as we choose if we build a condenser large enough and of the right focal length to match it.

In the case of a lens with spherical aberration we have no image proper, but, as has been said, a point of maximum concentration lying in front of the best image attainable. Accordingly if we put this point of maximum concentration in or beyond the objective, not only will the aperture plate in ordinary practice cut off the light from the outer portions of the condenser, but since the remaining central rays are brought to a focus beyond the objective, even the central part will require a larger source area to fill the whole cone than it would if the image were brought nearer the condenser. Thus we are using a larger condenser and larger source than we need. Thus we see that if we put the point of maximum concentration in or beyond the objective, spherical aberration but advances the image formed by the effective central rays further along the path and so increases the area of source required.

Now let us see whether there are practical difficulties in filling the cone. Let us consider the two sources in most common use.

First the arc. The intense heat of the arc means the condenser cannot be put close to it with safety. This means that to get an image to cover the section of the cone even at the aperture, it must be far from the condenser, which means a large condenser, or the arc must itself be large, which means high amperage. In practice it has been found impossible to meet these conditions. Accordingly, to get uniformity of illumination over the whole film, a relatively long focus condenser is generally used of a size considerably smaller than sufficient to cover the cone. (Fig. 1 of the paper). The great intrinsic brilliancy is relied upon to make up for the inefficiency of the optical system. In this case with an objective of average size the aperture is certainly the place for the image. Spherical aberration will necessitate the aperture near the point of maximum concentration for uniform illumination as the paper points out.

Second, the incandescent filament. This has a relatively low average brilliancy, but because of its size and the fact that it can be placed close to the condenser without excessive breakage the optical system used with it can be much more efficient. In fact with an energy dissipation but a fraction of the arc, the entire area of the largest objectives can be utilized. The power necessary for maximum illumination could be still further cut down, as has been shown, if the source could be focused on the aperture. This is impractical because with any incandescent lamp now in use the illumination over the entire filament area is not uniform. If this variegated pattern were focused on the film the objective would throw on the screen a picture not only of the film but of the filament as well. In order to avoid this it is necessary to focus the source at some other place, and as we have seen above, the most efficient region is between the aperture and the objective—the further we go from the aperture,

the more uniformly it is possible to light the screen and the larger must be the source.

If we consider the cones of light bounded by the lines drawn from a point on the edge of the condenser to the top and bottom of the source and of the image (considered in the objective) we can readily see that, due to excessive bending caused by spherical aberration, the emerging cone will not now just fail to pass the aperture, but that part of the light will go through the aperture and of course fail to strike the objective. We shall then get the same illumination no matter how much we increase the spherical aberration until it reaches the point where the top of the cone passes through the aperture opening. Any further aberration will mean a loss of light at the edges of the screen. Of course, this allowable angular deflection due to aberration, depends on the size of the source, its distance from the condenser and the size of the condenser. Spherical aberration then decreases the light lost at the aperture plate and spreads this light out in a hollow cone outside the objective aperture. Thus whereas without spherical aberration this light was lost on the aperture plate, with spherical aberration it is lost on the objective mounting. It should be noted that increasing the size of the objective to include this light, though it would undoubtedly put more light on the screen, would put half as much additional light at the edges of the picture as at the center and we should have an un-uniform lighting similar to that obtained when the spherical aberration exceeds the amount indicated above. The only disadvantage of a little spherical aberration is the heating of the film by the passage through it of light the objective cannot use. There is a slight advantage due to the blurring of the filament image allowing it to be brought closer to the aperture without appreciable unevenness of illumination and accordingly reducing the area of the source required. And right here let me say that when we blame one part of the optical train for "wasting light," as we call it, we must be careful to see that the saving of the light by this will not merely necessarily transfer the "waste" to another place.

We see then that the only advantage in practice in putting the image of the source or, in case of a condenser having spherical aberration, the point of maximum concentration at any other place than the aperture is to avoid an unequal light distribution rather than to get a greater total amount of light on the screen or to save energy.

In closing a discussion already entirely too long, I should like to say just a word of caution on two points.

First that we be extremely careful in the use of the term "point source" as the assumption of such a source is sure to be confusing, if not actually dangerous to the truth of the conclusions we draw. There is no source of light now in use for projection purposes on the appreciable size of which the calculation of the optical train and its arrangement in the projector do not depend.

The second point I wish to make is that we should be sure that when we say "aperture" or "diameter" of a lens, be it compound or simple, we mean effective opening, that is, the opening of an equivalent simple lens situated at the optical center of the combi-

nation considered. It seems to me that the paper in urging the adoption of what it calls a short "back focus" is perhaps a little confusing on this point. Certain it is that with the small field and large aperture usually used, if the first lens of the combination were put close to the film, this lens might be made smaller than the others, but this certainly does not mean—as the paper seems to imply—that with this arrangement we can then use a small front lens (and so avoid shutter difficulties) and get the same picture on the screen—for it simply cannot be done.

Putting the rear combination nearer the aperture means, other things being equal, taking the front combination further from the aperture if the optical center, and so the focal length, of the objective is to remain fixed. This will mean that, though the first combination does bend the rays into a less rapidly diverging beam, the front combination being further away must be the same size as before to take in the whole of this beam. We may put the rear combination close to the aperture and so make it smaller, but the front lens can be no smaller than it would have to be were both combinations of the same size, as at present. The small rear combination may possibly give a cheaper lens; it will certainly not give a more efficient one. In fact, if this change involves the introduction into the lens of a third combination, as the paper suggests, and if there is a 10% additional reflection due to these additional surfaces, we shall have 10% less light on the screen. There are but two things that determine the size of a light cone a lens will take —the focal length and the effective aperture under the conditions of projection. The efficiency of transmission, which depends on the design of the lens, determines the percentage of the light actually falling on the lens that reaches the screen. This then is of equal importance with the aperture and a 10% loss here is equivalent to a loss of 10% of the cone.

In motion picture practice the effective aperture is never appreciably larger than the opening of the front lens. With the same size picture then, as long as the rear combination does not diaphragm the cone of light, it makes no difference in the size of the cone of light the lens will take, where the rear combination is placed, and any movement of the condenser and consequent change in the cone of light can be handled by a short lens as readily as by a long one. The paper suggests that increase in objective size alone will not take care of a greater cone of light through the aperture plate, but that the rear combination of the objective must be close to the aperture. To this I cannot agree. Given the focal length of the objective the one and only thing that determines the size of cone that can be covered is, to my mind, the effective diameter of the objective, and we may leave the relative position of the combinations entirely to the lens designer.

Just one more word. The paper speaks of the difficulty of using a large objective with a shutter. This may be a difficulty with the present shutters, but it seems to me there can be no real objection to making a shutter large enough to operate with any objective that can possibly be built. Whatever the difficulty there is lies solely in the adapting of present machines to this larger shutter.

CONDENSER DESIGN AND SCREEN ILLUMINATION

By H. P. Gage

Note. The preparation of this treatise was prompted by a reading of Mr. Richardson's paper on "Some Phases of the Optical System."

The purpose of this article is to illustrate the desirability of suitable design in order to secure a proper balance between the different parts of the optical system of the motion picture projector and to attain maximum light efficiency. Also, there is described a simple and hitherto little used method of observing the operation of the optical system which enables one to determine easily and quickly whether or not the proper balance between the different optical parts of the system exists, and whether there are any parts of the mechanism which interfere with the light.

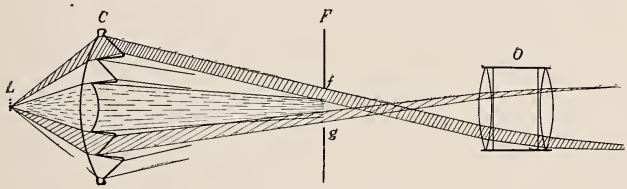


Fig. 1—Design of Corrugated Condenser

L One point of light source.
C Corrugated Condenser.
F (f–g) Aperture plate.
O Objective.

Motion picture projection depends upon mechanical devices for moving the film, and an optical system for projecting it. The optical system is not complete until the eye of the observer is considered, but in the present discussion it will answer to stop with the screen. The optical system for motion picture projection is illustrated in Fig. 4, the optical parts being enumerated and described below.

LIGHT SOURCE

The light source (L) may be any lamp having suitable brilliancy for the required projection. The lights most commonly used are the arc lamp and the special Mazda projection lamps. In the case of Mazda lamps it is usual to reinforce the lamp with a concentric spherical reflector (R). As the function of the reflector is to form an image of the filaments in the immediate neighborhood of the filaments themselves, the optical system is the same with the reflector as without it. The use of the reflector increases the light

thrown on the screen by about 70% when the reflector is clean and the bulb new. Figs. 7 and 8 show the glowing filament of Mazda lamps, with the spaces between the filaments illuminated by the images projected by a concentric spherical mirror.

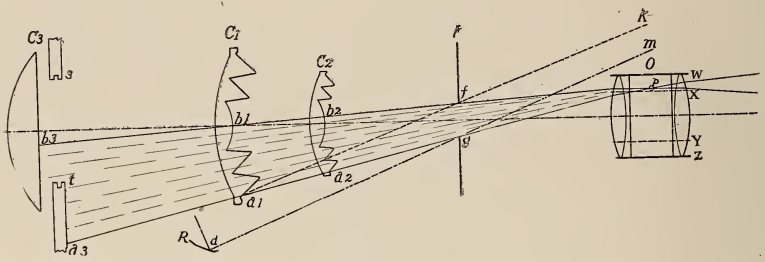


FIG. 2—Relation of the diameter and separation of the condenser to the diameter and focus of the objective

C_1 Large diameter corrugated condenser.
C_2 Small diameter corrugated condenser.
C_3 Front element of plano-convex condenser system.
s–t Opening in slide holder placed directly in front of the condenser. This removes considerable of the light from the condenser when so placed.
F (f–g) Aperture plate.
O Objective.
p A point in the objective.
b–f–p and a–g–p are the limiting rays of light which reach the point p after passing through the aperture plate.
A_1–f–k and d–g–m rays passing through the aperture which do not add to illumination as they cannot get through the objective.
W–Z Large diameter objective.
X–Y Small diameter objective which does not include the point p.

CONDENSER

The condenser (C) may consist of a pair of plano-convex lenses, of a meniscus lens combined with a double convex lens, or of a single corrugated lens of the general design illustrated in the accompanying figures. The function of the condenser is to collect the diverging light rays emanating from the light source and to concentrate them upon the picture to be projected so as to produce an intense but evenly distributed illumination.

APERTURE

The aperture is an opening in a metal plate 29/32 in. wide and three-fourths as high used to limit the edges of the picture. In immediate contact with this aperture is the strip of film on which is printed the picture to be projected. The location of the aperture plate and film is designated by F. It is generally assumed that both the picture on the film and the edges of the aperture are in focus at the same time.

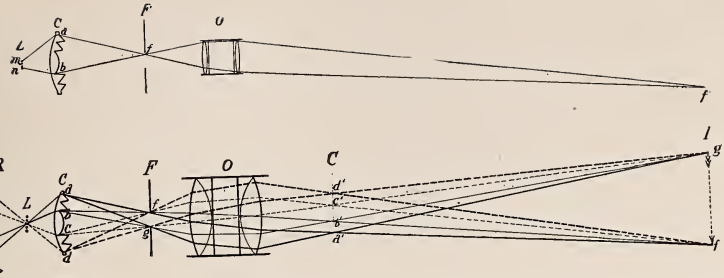


FIG. 3—Image formation of a single point on the film. All parts are drawn to scale

F Aperture plate

f Point on Film (located at extreme edge).

O Objective. The entire diameter of the objective is used to form the image of f.

f' Image of f.

C Condenser.

a–b Limits of condenser useful in illuminating f.

L Light source.

m–n Limits of light source useful in illuminating f. If the eye is placed at the point f' the entire area of the objective will appear filled with light.

FIG. 4—Image formation of condenser surface

F (f–g) Film located at the aperture is imaged by the objective O at the screen at I as f'g'.

C (a–b–c–d) Condenser, is imaged by the objective at C' (a'–b'–c'–d').

L Light source.

R Reflector.

O Objective. The objective is drawn of absurdly large diameter to better illustrate the formation of the condenser image. All other parts are drawn to scale.

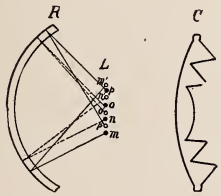


FIG. 5

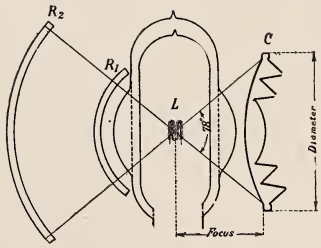


FIG. 6

FIG. 5—The use of a concave spherical mirror to form images of the filaments in the spaces between the filaments

R Concave spherical reflector.

L Light source. The filaments m, n, o, p, are imaged at m' n' o' p'.

FIG. 6. Necessary clearance between lamp filament and condenser, angle of light received by the condenser and necessary angle of the reflector

L Light source, filament of lamp.

R^1 Small reflector.

R^2 Large reflector.

The lines around the filament are to represent the glass bulbs: T–16, T–20, and GT–28.

OBJECTIVE

The objective is made up of several lenses of suitable design which are assembled in a single mount. The design of the objective must be such that it has all of the desirable qualities to be found in photographic objectives. These qualities are so fully and frequently described in photographic literature that it is unnecessary to go further into their enumeration. In the most elementary text books on Physics are to be found discussions of the "simple thin lens." Such a lens cannot be made of a single piece of glass on account of countless "aberrations," but if such a "simple thin lens" could be made it would have all the properties required of the photographic or projection objective. In fact, in theoretical calculations which involve the objective we can substitute for it an imaginary simple thin lens which has a suitable focus, position and diameter. Let us leave it to the skilled optician to design and construct this objective for us, allowing him to use any varieties of glass, any curvature and separation of the elements, any type of objective which he may deem most suitable for the purpose, but let us caution him to use no more glass-air surfaces than are necessary, for at each surface where the glass and air come in contact there is a loss of about 5%, *i.e.*, a loss of 10% for each lens or cemented doublet; and let us require him to make the diameter of all lenses as large as he can in order that the objective may transmit the greatest possible amount of light. When the optician's work is completed let him tell us what the equivalent focus of the objective is, also its equivalent diameter (if that should differ from the diameter of its lenses) and we will then put in our drawing a simple theoretical lens having this focus and diameter and all our calculations will come out exactly as if we had traced each ray through the complicated lens system of the actual objective.

The purpose of the objective is to form a real image I, (f'g', Fig. 4) of the film F, (f, g,) upon the screen. In addition, the objective forms images of everything on one side of it at some place upon the other side of it. For example an image of the condenser C, (a, b, c, d,) is formed by the objective O at the place C' (a' b' c' d'). If the condenser C is located too close to the film its image will lie near the film image, as in the case of stereopticon slides, and if the surface of the condenser is cracked this condenser image C' will lie so close to the picture image I, that disturbing shadows are seen. In ordinary motion picture projection as here illustrated there is no danger of imperfections or condenser rings appearing on the screen.

Dimensions of Elements

OBJECTIVE

The equivalent focus of the objective is fixed by the size of the picture which it is desired to project and the distance to the screen (throw). The necessary focus can be found in any of the

numerous tables which are published on the subject. For a given theater, the focus is fixed by the conditions in that theater.

The diameter of the objective should be as large as can be obtained in order to utilize as much of the light passing through the aperture as is possible. When using the arc lamp as an illuminant, experience has shown that it is much easier to obtain an even screen illumination free from shadows and dark corners with a large than with a small objective. With the incandescent lamp the entire area of the objective is utilized to image each point of the picture, hence a large objective will give a more brilliantly illuminated screen than will a small one. See Figs. 10 and 11. Objectives are regularly manufactured with free diameter as great as $2\frac{7}{16}''$ and equivalent foci of $5.62''$ or greater. The objectives studied in the preparation of this article had an equivalent focus of $5.62''$. One had a free diameter of $2\frac{7}{16}''$ and the other $1\frac{5}{8}''$, *i.e.*, photographically speaking they had a speed of f/2.3 and f/3.6 respectively. It is possible to make an objective of even greater speed than this and at least one has been made up on special order with a speed of as great as f/2.0 which worked successfully with motion pictures. The head of some machines will not take these large sized objectives. This is unfortunate as it imposes a limitation upon such machines which will be increasingly felt in the future. In general, the largest commercial objectives of $5\frac{3}{4}''$ focus or greater have a free diameter of $2\frac{1}{2}''$ and those of shorter focus have a smaller diameter, so that the ratio between diameter and focus remains about the same.

With the exception of Fig. 4, in which the diameter of the objective is drawn absurdly large in order to make clear the formation of the image of the condenser, the different optical parts are drawn correctly to scale, and the objective is drawn with $5\frac{1}{2}''$ equivalent focus, $2\frac{7}{16}''$ free diameter corresponding to the photographs.

APERTURE

The aperture opening (f, g) shown in the drawings is the standard width of $29/32''$.

CONDENSER

In a given projection apparatus the dimensions of the objective and the aperture are fixed, and the condenser and light source are the elements which must be varied in order to secure efficiency. While the condenser to be described was developed to meet the needs of the incandescent lamp the optical reasoning applies equally well to any light source.

As illustrated in Fig. 6 the clearance between the surface of the condenser and the filament L must be sufficient to allow room for the bulb. The greatest angle of light receivable by this type of condenser for efficient operation is 78° or 80°, and the reflector obviously must cover at least as great an angle as the condenser. The larger diameter reflector (R_2) is preferred as it is farther away and does not get as hot as does the smaller one. For the largest

bulb shown G-T-28 a condenser $4\frac{7}{16}''$ in diameter with $2\frac{1}{2}''$ focus answers well. The smaller and more compact condensers give the same efficiency but as they afford less space between condenser and aperture plate (Fig. 2) they are not much used for professional projection.

The general elements in the design of the corrugated condenser are illustrated in Fig. 1. This illustrates the method of bending the light originating from a single point of the light source. The fundamental principles involved in screen illumination are: first, the illumination must be even, without streaks or shadows, and second, that it must be sufficiently intense. The light from each point of the light source is collected in such a way that it evenly illuminates the entire aperture. This is necessary with the incan-

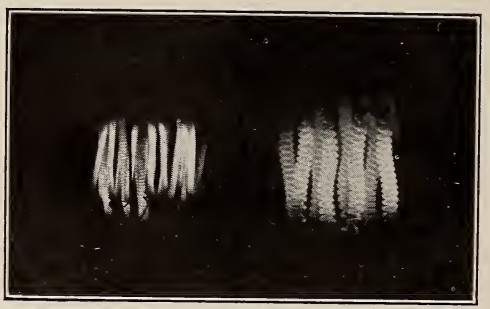


Fig. 7 Fig. 8

Fig. 7 (Left)—Filament of ordinary stereopticon lamp backed by spherical reflector.

Fig. 8 (Right)—Filament of special monoplane filament projection Mazda lamp backed by spherical reflector. After burning for some time the filaments bend slightly so that there are small dark places between the filaments even when using the reflector.

descent lamp, as it is made up of a number of sharply defined streaks of light separated by dark spaces. If the condenser design or adjustment is such that the illumination from a single point is non-uniform then the illumination from an incandescent lamp will be streaked.

The relation between the diameter and distance of the condenser from the aperture for maximum efficiency is fixed once the diameter and focus of the objective are determined upon. For a given point P in the objective to be effective in transmitting light to the screen from all points of the picture between f and g, Fig. 2, it must receive light between the points a_1 and b_1 of the larger condenser or between a_2 and b_2 of the smaller one. If the condenser is located too far away as in the case of C_3 (12″ separation between condenser and aperture) and especially if the condenser is diaphragmed down by the slide holder permanently fastened in front of it, as is now too often the case, it is evident that the objective is not functioning to full efficiency. (See Fig. 10 c and d.)

Light bent too sharply as in the case of the ray a_1fk is not useful nor would light such as d–g–m collected by an extra ring or reflector outside the condenser serve any useful purpose. Such light, while striking the film, would unnecessarily heat it, and, entirely missing the objective, would never reach the screen. Thus is determined the proper proportion between condenser and objective.

POSITION OF THE SHUTTER

There has been considerable discussion as to the proper position of the shutter. When the shutter is located in front of the objective (outside shutter) it is desirable to place it in the narrowest part of the beam. With the arc lamp as an illuminant, there is a restriction in the beam at the position of the condenser image, similar to C' in Fig. 4 and this is the preferable position for the

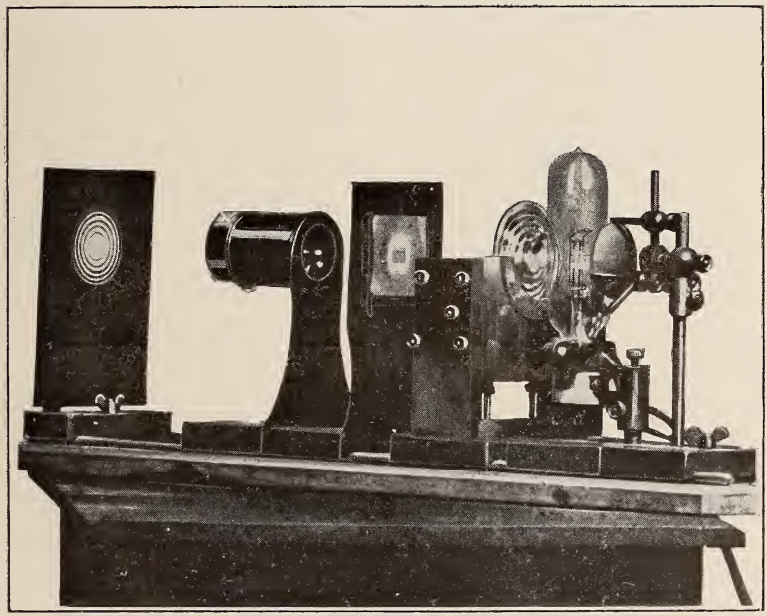


FIG. 9—Apparatus used in testing condensers. This shows the lamp, reflector, condenser, aperture, large objective, and screen placed at the aerial image of the condenser. The dark rings shown in this image do not appear on a screen placed at the usual distance for viewing the pictures.

shutter. With the incandescent lamp, however, owing to the closeness of the condenser to the objective, its image is larger than the objective, and the narrowest part of the beam is immediately in front of the objective. This is also illustrated in Fig. 3 where the extreme edge rays of light diverge from the objective as does the lower ray in the illustration.

Observation of Optical System

The method of observing the optical system to determine whether the necessary conditions are fulfilled to secure maximum efficiency is illustrated in Fig. 3 and the photographs, Figs. 10–12. In Fig. 3 the point f, located at the edge of the aperture, is so illumi-

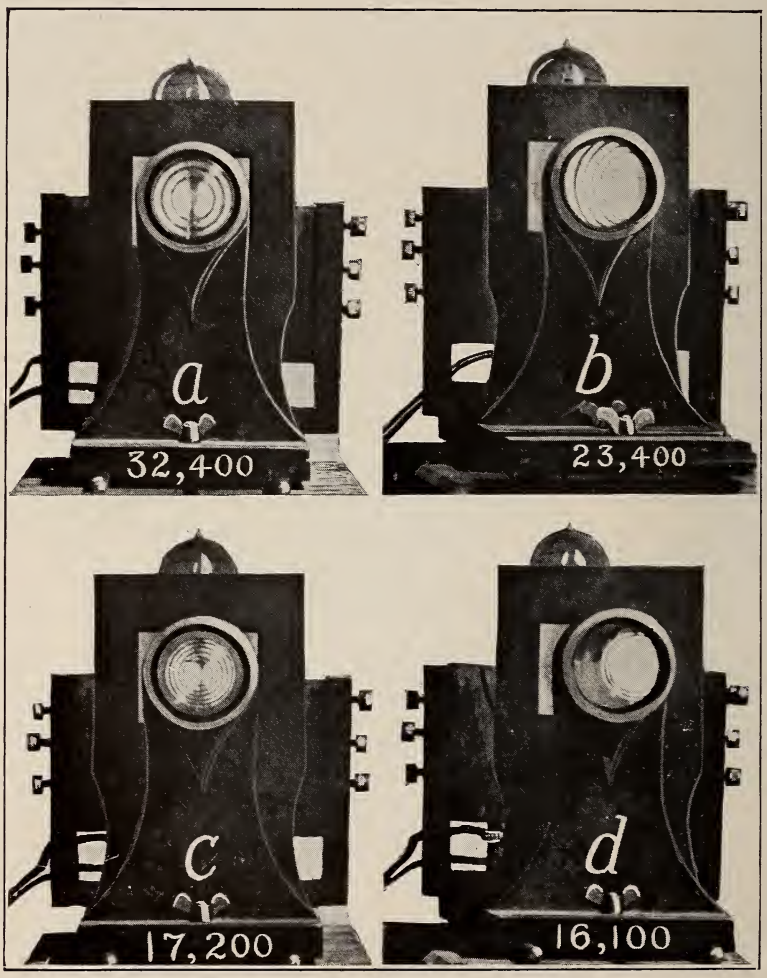


Fig. 10—Corrugated condenser, $2\frac{7}{16}''$ diameter objective

Appearance when the eye is placed near the screen and the objective is observed through dark glasses. The figures represent the relative intensity of the light coming through the objective in the direction being observed.

a. Center of picture, $6\frac{1}{2}$ separation between the condenser and the aperture.
b. Edge of picture, $6\frac{1}{2}''$ separation.
c. Center of picture, $12''$ separation.
d. Edge of picture, $12''$ separation.

nated that the light rays spreading out from it diverge by just a sufficient amount to completely fill the objective with light. These rays are again converged by the objective to form the image f' at the screen. As the drawing illustrates it is evident that if the light rays diverged over a wider angle some light would be lost by missing the objective, while if the light diverged a less amount, the entire area of the objective would not be functioning.

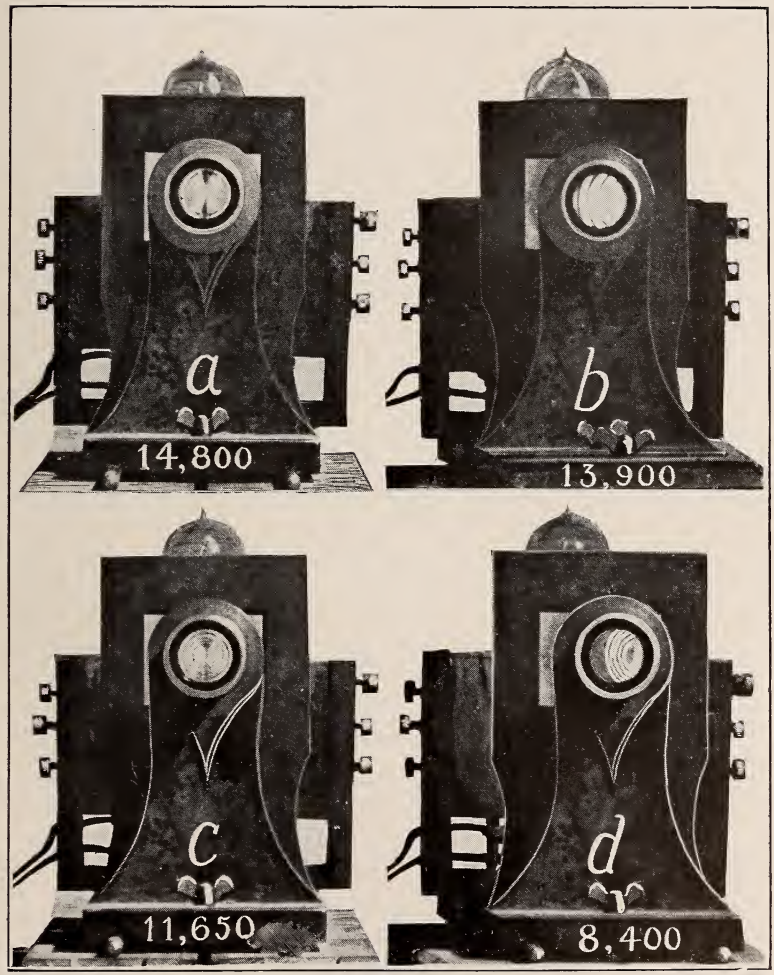


FIG. 11—Corrugated Condenser, 1⅝″ diameter objective

a 6½″ separation between the condenser and the aperture plate, from the center of the picture.

b 6½″ separation, edge of picture.

c 12″ separation, center.

d 12″ separation, edge.

If now the eye is placed near the screen and looks back at the objective one sees a bright spot of light which may or may not fill the entire area of the objective. In order to do this with the arc or incandescent lamp burning at full brilliancy it is necessary to use either smoked glasses or to place a piece of heavily smoked glass between the light and the condenser or just in front of the condenser. The last position is preferable as it enables the observer to obtain a general view of the apparatus at the same time that the size of the light spot is observed. The result of such observations is shown in Figs. 10–12.

The apparatus used in the experiments here described is illustrated in Fig. 9. The different parts are the same as shown diagrammatically in Fig. 4 and consist of an incandescent lamp backed by a spherical reflector. The condenser serves to concentrate the light from the lamp upon a standard aperture. The objective serves to form a real image of a picture located at the plane of the aperture upon a screen in front of the apparatus. In the apparatus as illustrated a movable screen has been placed in the position occupied by the condenser image. With this set-up, which is used in testing all condensers, it becomes readily apparent that if the condenser contains an optical defect so that light from some portion of it does not pass through both the aperture and the objective the image will show a shadow at this point. Condensers which do not show all of the rings properly functioning are eliminated.

The tests illustrated in Figs. 10 to 12 were made by setting a camera with a telephoto objective of 50″ equivalent focus (x8) about 20 ft. in front of the apparatus. Two exposures were necessary, a 5-minute exposure to show the general outlines of the apparatus and an extremely short exposure to show the light spot coming through the objective. In Figs. 10 and 12 is illustrated the large objective with $2\frac{7}{16}''$ free opening and in Fig. 11 is shown the smaller objective $1\frac{5}{8}''$ free opening. Both are marked $5\frac{1}{2}''$ equivalent focus, and are supposed to be identical except in diameter. Figs. 10a and 11a show the appearance with the camera objective in the direct axis of the beam, that is, located in the position of the exact center of the picture. The separation between the condenser and the aperture is $6\frac{1}{2}''$ as is called for in the theoretical design for this combination illustrated in Figs. 1 and 2. Note that in the cases of both 10a and 11a the entire area of the objective is filled with light, and hence both objectives are contributing as much light to the center of the picture as they possibly can but that on account of its greater area, the larger objective is able to contribute more light than the smaller one. In Figs. 10b and 11b the same separation is used, but the camera was so placed that it was at the extreme edge of the picture, *i.e.*, if it were even one inch farther towards the side, no light from the lamp would reach it. This shows both the large and small objectives still completely filled with light.

If instead of using the corrugated condenser, as previously illustrated, it is desired to use the ordinary plano-convex condensers, a separation between the front of the condenser and the aperture plate of much more than the $6\frac{1}{2}''$ previously referred to is

required. With the incandescent projection lamp even illumination can hardly be secured with a less separation than 12″, while for operation with an arc lamp, a separation of at least 16″ is recommended and a separation of as great as 22″ seems to be required for low amperages. The result of employing two 7½″ plano-convex condenser lenses with the incandescent lamp, and the large objective, using a separation of 12″ is shown in Fig. 12. The dark spaces in the condenser image are the result of the dark spaces between the filaments of the lamp. Note that the objective is

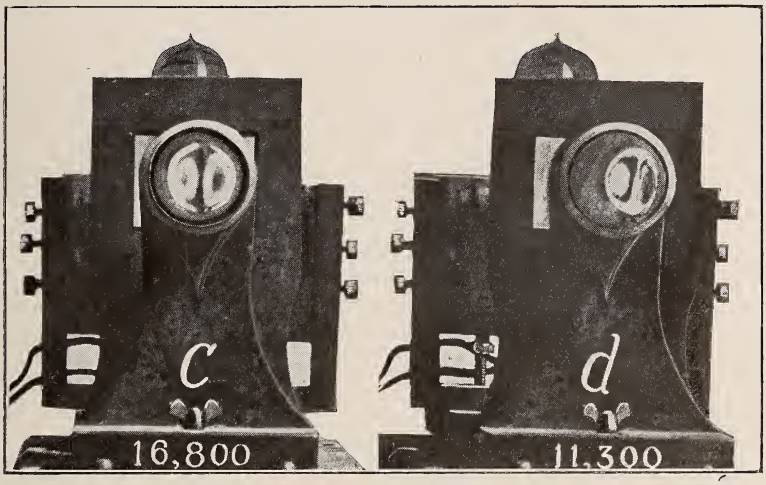


Fig. 12—Plano-convex condenser system, 7½″ focus lenses, 2 7/16″ diameter objective

c 12″ separation between the surface of the front condenser lens and the aperture plate. From the center of the picture.

d 12″ separation, edge.

not entirely filled with light even when looking directly into it (Fig. 12c), and when looking at it from the edge of the picture the space between the edge of the condenser and the objective is increased and part of the area of the condenser is cut off. It is entirely possible to employ the corrugated condenser with a separation of 12″ and get practically the same results as with the plano-convex condenser system if this greater separation is desired. The result in the case of the large objective is shown in Fig. 10c and d and in the case of the small objective in Fig. 11c and d.

The comparison between different illumination systems can be illustrated photographically, but the engineering data for discriminating between them are not complete until photometric measurements are made to determine the ability of each to illuminate the screen. It is often a difficult matter for the eye to discriminate illumination differences of 10% to 25%, but small

differences of this size are by no means insignificant when counting the cost as recorded at the meter. Illumination tests were made by substituting the test plate of a portable photometer for the camera objective used in taking the photographs illustrating this article. In making such photometric tests the actual screen illumination obtained with a given system depends upon so many elements, such as the equivalent focus of the objective, magnification, screen distance, density of film exhibited, exact shutter design, individual lamp used, age and condition of lamp, reflector, and line voltage at the time of making measurements, that it is hardly within the scope of the present paper to give detailed measurements of actual screen illuminations, but there are recorded comparative measurements of each system in Figs. 10-12 and in table 1.

Table I

SCREEN ILLUMINATION WITH DIFFERENT CONDENSING SYSTEMS FOR LARGE AND SMALL DIAMETER OBJECTIVES

	Separation between Condenser and Aperture Plate	Two Plano-convex Condenser Lenses $4\frac{7}{16}''$ diameter $7\frac{1}{2}''$ focus		Corning Corrugated Condenser $4\frac{7}{16}''$ diameter $2\frac{1}{2}''$ x $6\frac{1}{2}''$ foci	
	Center	Center	Edge	Center	Edge
Large Objective.....	$6\frac{1}{2}''$	Streaked	Streaked	32,400	23,400
$2\frac{7}{16}''$ Diameter..... $5\frac{1}{2}''$ Focus.....	$12''$	16,800	11,300	17,200	16,100
Small Objective.....	$6\frac{1}{2}''$	Streaked	Streaked	14,800	13,900
$1\frac{5}{8}''$ Diameter..... $5\frac{1}{2}''$ Focus.....	$12''$	12,200	9,300	11,650	8,400

Examination of Table 1 shows us that if the plano-convex condenser system is used with a $6\frac{1}{2}''$ separation it is impossible to get an evenly illuminated field with either objective. With a $12''$ separation a fairly even field may be obtained, free from streaks, and the intensity at the edge of the picture is at least 70% of that at its center. The intensity is substantially the same as with the corrugated condenser for the same separation. To definitely determine whether with this separation there is any consistent difference between the plano-convex and the corrugated systems would require a much more extended series of measurements than was possible to make at the present time. The table does, however, show definitely two things.

First, with every condenser system a much higher screen illumination is obtained with the large than with the small diameter objective.

Second, with a given objective a much higher illumination results with the corrugated condenser at $6\frac{1}{2}''$ separation than can be obtained with either condenser at $12''$ separation. The fact that owing to its design the corrugated condenser gives an even screen illumination at $6\frac{1}{2}''$ separation, whereas the plano-convex condenser gives a decidedly uneven or streaked illumination with a separation substantially less than $12''$, points to the conclusion that for highest illumination efficiency the corrugated condenser used at $6\frac{1}{2}''$ separation is the most desirable condenser to use in connection with the Mazda projection lamp.

Conclusions

From the foregoing experiments as illustrated by diagrams, measurements and photographs it is apparent when using the incandescent lamp as an illuminant that:

First, a relatively large diameter objective is to be preferred.

Second, a short separation between the condenser and aperture plate, suited of course to the diameter and focus of the objective, is advantageous.

Third, the great advantage of the corrugated condenser is that an even screen illumination can be secured with a shorter separation between the condenser and the aperture than is possible with the plano-convex condenser system, thereby securing the greatest possible brightness of the picture.

Fourth, to get the greatest screen illumination when using the incandescent lamp the combination of all of the optical elements working at their greatest efficiency is required, including good quality reflector, proper adjustment, large diameter objective, and corrugated condenser used at the separation of 6½″ from the aperture plate for which it was designed.

ADDING COLOR TO MOTION

By William V. D. Kelley

Not long ago I ran across this very interesting statement by Dr. Foote:

"The fact is, we have kept on discovering and forgetting and then re-discovering, ever since man began to think."

I was not there when man began to think, so naturally I cannot verify this part of Dr. Foote's statement. I can testify, however, to the fact that in the field of natural color photography and color photography as applied to the motion picture, we have kept on discovering and forgetting and then re-discovering.

The records show that as far back as 1785 natural color photography was engaging the attention of men of science. Men discovered at that time; later, men forgot; and then men discovered again.

I have seen samples of work done by the "bleach-out" process which was first suggested in 1813 by A. Vogel.

In 1861 the modern theory of three-color photography came to be recognized, and during the succeeding forty-five years some progress was made, slow and halting to be sure, but nevertheless, progress, in developing processes for recording scenes in color.

In the year 1900, while I was residing in London, England, an American, Mr. Tripp, was demonstrating the McDonough process of color screen prints, and later in that same winter I attended a lecture and demonstration of the Sanger-Shepherd process at the Royal Photographic Society.

At that time I was connected with the American Mutoscope and Biograph Company, and, therefore, motion picture photography and the possible application of adding color to motion was intensely interesting to me.

All of the different forms of producing natural color pictures were well known at that time, for we had the Lippman process, which is based on the interference of light waves, the McDonough, which is additive and the Sanger-Shepherd, which is subtractive.

Mr. F. E. Ives was demonstrating his Kromscope, which is an additive process, while in our Mutoscope parlors we were showing in a penny slot machine, six views of subtractive photographs made by Gaumont.

The first motion picture films in natural colors to receive any degree of publicity were those of Smith in 1906, which were fathered by Urban of international fame, although private showings of similar films had been given some time previous to that.

The shortcomings of that process led men to see possibilities of applying the Sanger-Shepherd method to Kinemacolor negatives, and their results were promptly recorded in the British Patent Office. Some of these patents have nearly expired, but none has yet been reduced to a working basis and none has been shown publicly, to my knowledge.

So you see, in speaking on the subject of "Adding Color to

Motion," we have a certain background of discovering and forgetting and re-discovering which will not permit any one at the present time to say that adding color to motion is an entirely new science.

In the *British Journal of Photography*, December 6, 1912, Mr. H. Quentin, referring to screen plates says, "And thus it is that in screen plate color photography the chief merit consists not in inventing a screen, but in producing it commercially." In the making of Prizma pictures in natural colors, the industry with which I have been mainly identified for a number of years, our problem has been largely one of devising means and developing processes that would make motion pictures in natural colors commercially practicable.

In a report for the Society of Chemical Industry in 1916, Mr. B. V. Storr, of the Ilford Company, London, said, "A number of patents have been published both for multicolor screens and for various details in the production of positives. In the latter, apart from the mechanical difficulties of registration, the chief problem appears to be to get a method of coloring which will give a uniform tone throughout the length of film."

We had considered for some time that other steps were of more importance in the making of Prizma films, but we found at last that our main stumbling block in making the present product finally proved to be the matter of coloring.

The successful making of small pieces of film by the known methods used in photography for toning or the patented descriptions of coloring methods were found to be impracticable when applied to the commercial handling of films in long lengths, so it became necessary to work out a new method and means for coloring. This we successfully accomplished.

Our problem contained several elements that required the development of new processes in order to accomplish the result of co oring long lengths of film commercially. The film may be 200 feet long, in which length, as you know, there are 3200 separate color transparencies, all very much alike with the exception of those parts showing the steps of movement. To make each picture exactly like the next and to duplicate the copies so that they are all alike, was the problem that had not been satisfactorily solved before.

In letterpress printing, if the copies vary, no damage is done, as one seldom sees many prints together for comparison and the poor ones are discarded.

With motion pictures there is not so much chance for discarding individual pictures, for if we did the film would consist mostly of patches. This problem was overcome, and film has been produced in quantity, so that each individual image-bearing area is substantially complete in colors which may be seen by holding the film in the hand.

COLOR RENDITION

I read that, "It is not possible for anyone to explain how or why we see colors, and probably it never will be." We have our theories

which stand up well against practice, but are unable absolutely to check back and prove them out. A good portion of the audience that view natural color pictures see colors at variance with what we term normal vision. Others attempt to judge colors from their own conception of what they should be. For example, the color of the waters of the Pacific Ocean varies from that of the Atlantic Ocean, and to one who has not noted this difference by personal visit, the color rendering may be judged to be unsatisfactory. Don't be hasty in forming your judgment as to the color correctness of a picture—your neighbor may be seeing it differently from you. I have seen a picture projected in which the color of certain flags appeared as orange to me, while to my associate they were pink.

THE EXHIBITORS

In the "British Journal of Photography" of February 1, 1918, on page 8 of the Supplement, there is added to an otherwise more or less correct statement, the following:

"Altogether, it does not look as though the commercial prospects for additive processes of color cinematography are very encouraging. *We have still to wait for the ideal color film which can be bought all complete by the yard and inserted for projection into the standard cinematograph lantern.*"

On December 28, 1918, Prizma began releasing weekly natural color films which can be "bought all complete by the yard and inserted for projection into the standard cinematograph lantern."

From the exhibitor's standpoint that is the big accomplishment; for all previous natural color films required either high projection speed, so high that such films only have one-third their normal life, or an attachment, or a complete new projector. Nearly all of these forms, in actual practice, required the attention of a special trained operator from the home office, or what is just as troublesome, a course of instruction to the theater operator, before the films could be left with safety and assurance of successful shows.

THE COLOR WORKERS

For the information of those that like the "ins and outs" of the process employed will say:—

The negatives are made through two sets of complementary colors, or as we usually say, four colors.

The four color values are dyed in two colors. That is to say, the reds and oranges are dyed a red-orange color, while the greens and green-blues are dyed a color complementary to the red-orange colors used.

In many subjects when the film is examined in the hand, there is a noticeable difference in alternating images, in which case one will favor the green-blue, and the succeeding image will favor green. These blend without pronounced flicker on projecting at the customary projection speed.

The projection is on the additive principle of mixing lights while the production of the image is accomplished by the subtractive principle.

Registration of two images on the same area, done continuously in long lengths and consistently accurate, is had to 1/10,000 of an inch. This, in spite of the fact that developed negative shrinks to an average of $\frac{1}{16}$ of an inch in each foot, sometimes as much as $\frac{1}{8}$ of an inch, while there is a corresponding shrinkage laterally. The fresh positive at the time of printing is still of standard width and length, and consequently of different length and width as compared with the negative.

The above paragraphs place the matter before you in brief language. Rather than enlarge on each item by tearing to pieces and analyzing each step, I have prepared a film that demonstrates most of the steps.

So that you will know what to look for I will add that we are using a projector that permits us to stop and view the films as we would lantern slides. You will, therefore, see the difference between additive and subtractive colors in pictures and not in words, for has not someone said "that a reel of pictures will tell more than 300 pages of printed matter and in a much shorter time." You will see the nature of the colored images when separated into single colors. The results of incorrect coloring. What registration means. The accuracy of the color rendering for we have the pictures on the curtain and the fabrics that were photographed in our hands. A duplicate of the original negative will be seen, which shows the color values but which of itself is devoid of color.

ATTACHMENTS TO PROFESSIONAL CINEMATOGRAPHIC CAMERAS

By Carl L. Gregory, F.R.P.S. and G. J. Badgley

It is almost as certain as death and taxes that no professional motion picture studio photographer is entirely satisfied with any model of camera that is manufactured to-day.

The Cinematographer does not consider that he is ready to take a picture until he has camouflaged his camera with more attachments than a Ford owner can buy for his "tin lizzy." This is not so strange when we stop to consider that very few of the professional cameras available to-day are equipped with more than one or two of the many devices which are required to obtain the varied effects that are to be seen in practically every motion picture production. With the exception of the American built Bell and Howell camera, nearly all of the better makes of motion picture boxes are, or rather were, manufactured in Europe, for with the exception of a limited number of Pathe's, this production was entirely cut off by the great war. It would not be fair to pass on, however, without referring to the fact that a great number of sporadic attempts have been made in this country to manufacture motion picture cameras, but for one reason or another, none of the attempts has been successful, if we accept as a criterion the verdict of a large percentage of professional cinematographers.

It is hardly fair to class a camera as being a professional studio camera unless it has held its ground day after day and month after month under the grinding routine of steady studio production. Such an arbitrary classification should not be regarded as detracting from the merits of certain types of cameras, which are yet in the process of evolution and have not as yet, for one reason or another, come into general use for studio production. A number of models of high merit have been exhibited, which would have been eagerly tried out in the studios, if a sufficient number of them had been placed on the market, so that they could have been given a fair trial. Doubtless, some of these excellent models, which have relapsed into a comatose condition during the restricted period of the war, will now be revived and receive a proper introduction in the Cinematographic world. It seems reasonable to prophecy that the Cine camera of the future will be sold with a number of standard attachments in much the same way as the sewing machine is sold with an equipment for producing all sorts of fancy frills, tucks, pleats and ruffles. In much the same way must the professional camera be provided with attachments for producing dissolved vignettes, fades, irises, etc. Foremost among these attachments is the one for producing dissolves. Formerly, all dissolving and fading was accomplished by means of the iris diaphragm. Producing a fade by means of the iris under certain conditions is very difficult, as very few iris diaphragms are constructed so that they will close completely.

In making a fade, it is necessary that the exposure be diminished from the maximum to zero in a uniform diminuendo; or, in producing what is styled a fade-in, commenced at zero and with a uniform crescendo developed to the maximum normal exposure. Under good lighting conditions, the arc of movement from the normal exposure opening to that of a completed enclosed iris is extremely small; so that a gradual decrease through this small arc is exceedingly difficult to accomplish in a uniform manner, especially as it is almost always complicated by the fact that the iris will not close completely and a complete fade-out can not be obtained. The general practice, where this complication arose, was to place the hand over the lens as soon as the iris was closed as far as it would go; thus ending it abruptly without accomplishing the final diminishing point. A dissolve, which is a fade-in superimposed upon a fade-out, would be farther complicated by the fact that, in many cases, a scene which dissolved into another might be taken under poor lighting conditions and be succeeded by one taken in strong light, so that the arc of movement used in producing the diminuendo in one might cover several times the angle of the arc of crescendo in the other. This leads to the conclusion that the only method of obtaining a uniform dissolve would be to gradually decrease the exposure time by gradually overlapping the sector blade of the shutter as it revolves; thereby gradually decreasing the exposure. A number of excellent mechanical devices for advancing the sector blade of the shutter have been perfected. They are of two classes; the manually operated and the automatic. The manually operated is self-explanatory, as it is manipulated by the hand, while the camera is in operation. The automatic type is operated by the movement of the camera itself being brought into action at the required moment by throwing in a clutch driven from some part of the camera mechanism. With the manually operated dissolve, the fade may be of any desired length, whereas with the automatic, only a certain pre-determined length of fade may be produced.

In the Shustek camera, the advancement of the sector blade is accomplished by a differential gear.

In the Kronik Brothers' Camera two sector blades are advanced simultaneously from each side of the shutter opening by means of a pin passing through two curved slots in the sector blade, and a straight slot in the covering blade, this pin being actuated by a yoke which is moved in and out by a sliding sleeve on the shutter arbor. Only a very few of either of these types of cameras have been manufactured. The most common device for closing the sector blade is that of a spirally actuated sleeve upon the shutter spindle. In the Badgley shutter, which has been installed in dozens of Pathe and other makes of professional cameras, the sector blade is attached to a sleeve on the shutter arbor, which is hollow. A rod sliding in the hollow arbor carries a pin extending out through a straight slot in the arbor and engaging a spiral slot in the sleeve. By thrusting this pin-carrying member in or out of the shutter shaft, the relative position of the sector blade to the shutter opening is changed. A worm and gear train which may be thrown in or out of engagement with the camera mechanism by means of a clutch

operates this thrust rod slowly in or out and simultaneously moves an indicator which shows how far this sector blade is open or closed.

In the Bell and Howell camera and in the Duplex printing machine a spirally actuated sleeve also closes the sector blade across the shutter opening in the manner just described except that the details of the mechanical design are somewhat different than those employed by Mr. Badgley.

In all of the automatic installations so far mentioned the length of dissolve is pre-determined, generally three or five feet, and cannot be changed. An automatic shutter dissolve, in which the length of dissolve can be altered at will, would be a desirable feature in a professional camera, providing that it be not too complicated.

Mr. Carl Akeley has invented a shutter of this type, which can be set at practically any length up to ten feet, but has not yet brought it out. The demand for an adjustable automatic shutter dissolve does not seem to be very insistent, as in most of the exceptional cases where the standard automatic dissolve is not of the required length, the automatic mechanism is not used and the dissolve is manually operated to the desired length.

After considering the dissolving shutter as being the most important feature to embody in a cinematographic camera for professional use, there are a number of other features which are so nearly of equal importance that we will not attempt to arrange them in order of their usefulness, but simply take them up one after the other as they occur to our mind.

Intimately concerned with the operation of the shutter and in fact all manipulation of the camera is the amount of film used. Most cameras, even of the cheapest variety, have some kind of crude counter for recording the film footage; but the word crude is used advisedly, as most of these counters which are found installed in the camera when purchased, are of the crudest kind. It is often necessary in trick work and vision or double exposure to know the exact footage and even the exact frame at which a double is to commence or end; so that it is only by means of an accurate counter, or a lot of unnecessary counting and calibration by the operator himself, that he can interpose his trick work in the exact place in the film where it should go. There are a number of very excellent revolution counters upon the market, which count accurately backward or forward and which indicate in large plain figures their results, that may be easily installed in a camera and in such a manner as to count either footage, crank turns, or frames, as may be desired. The counters manufactured by the Veeder Manufacturing Company of Hartford, Conn., may be taken as representative of the kind of instrument useful for this purpose. One of the double counters, in which one face gives the total and the other face a sub-total, the sub-total face of which may be readily set back to zero by means of a thumb-nut, is excellent for our purpose. It would be a comparatively simple matter for the manufacturer to change one of these counters so that the unit wheel could be divided into sixteen parts and thereby record each individual frame, allowing the other numbers to record the footage. The Bell and Howell people have made a counter of this type by

combining a wheel of their own divided into sixteen parts with a Veeder counter, but unfortunately, in attaching it to their camera, has rendered it worse than useless; first, by attaching it to the one turn spindle which prevents the use of the trick crank; second, in order to obtain a set-back feature, made it frictionally operated so that its record, on account of slippage, is more often inaccurate than correct.

The Eastman Company has inaugurated an innovation with their negative film, which to be of any use, practically necessitates the use of an accurate counter. This innovation consists of photographing on the perforation edge of every foot of negative film before shipping a consecutive footage number which is recorded on the box in which it is shipped so that we may have for example, a roll of film 400 feet long, upon the edge of which we have recorded the consecutive numbers from 437,000 to 437,400. If, then, we keep track of our scenes for the future information of the cutter and editor, it is necessary for us in exposing this film to keep an accurate footage record so that our recorded numbers for the scenes will exactly coincide with those given to the cutter for his information in making the first continuity and for keeping track of all of the scenes in the production throughout all of his operations with the same. If this system were followed out, a tremendous amount of labor would be saved in the cutting rooms, as it would not be necessary for the cutter to look through roll after roll of film to identify a certain scene, as he could merely refer to the assistant director's record and tell in an instant by looking at the record number on the edge of the film, whether he had the right piece of film or not. This system, is of course complicated by the high numbers required to avoid duplication, especially in studios where there are a number of directors working at the same time, as it would be possible for two different directors to have rolls of films carrying the same consecutive footage numbers or even possibly, though not probably, according to the law of chances, that the same consecutive numbers might occur twice in the negative rolls used in the same production. A much more simple method which, as far as we know, has not yet been used, would be that of a counter record which would be automatically photographed upon the edge of the film during the operation of the camera, so that each production might have its own designation symbol and consecutive footage number impressed at the side of every frame throughout the negative of which the assistant director would keep record as the scenes were taken for the information of those in charge of all cutting operations.

While many of the devices of trick photography—so called—are frowned upon by the modern director, the striving after artistic effects has more greatly strained the resources of the photographer than any of the visioning back devices that were formerly the stock in trade of the old-time director. Dual roles are still employed to exploit the versatility of our stars and results which once were called trick photography now masquerade under the more euphonious title of photographic effects. The modern, up-to-date photographer has probably more use for inside and outside mattes than he did during the era of trick photography, but he now employs

them with a delicacy and finesse unthought of a short period back. If he does double exposure now it must be so accurately done that there is no weave or shifting visible between the primary and secondary exposures. He goes in for beautiful cloud effects and color values, using color screens, Vignetting devices and panchromatic films. His exterior iris must be so adjustable that its last encircling dot in closing may vanish at any given point in the frame and with any desired degree of diffusion. He must be able to give soft focus effects, fading away into indefiniteness at the edges, and yet retaining in his principal objects at the center of the film a sufficient degree of clarity to avoid over-stepping that hazy boundary between a pleasing softness and an out and out fuzzy-wuzzyness. For these effects he requires inside and outside mattes, slotted lens hoods, round and square closing vignetting devices, with perhaps a half dozen irregular or odd shapes closing in odd geometrical forms in addition, to give him a pleasing variety from which to choose and, in addition, have his camera so built that these devices may be attached and employed without unnecessary delay. In the employment of inside mattes it is generally necessary that they come in as close proximity to the film as it is mechanically possible to place them without coming into actual contact with it. The inside matte, in contradistinction to the exterior matte, is employed where the lines of demarcation between the part matted out and the part photographed should be as sharply defined as possible. Where a double exposure joins two of these sharply defined lines of demarcation, the cutting of the mattes so that the two exposures may exactly coincide without over-lapping or leaving unexposed space between is a matter of extreme mechanical precision and the mattes themselves and the grooves in which they are held must be made with the greatest of care. Every operation connected with the use of inside mattes must be carried out with the greatest precision, for the slightest movement of the camera will instantly reveal their use where two or more mattes are used in making a composite picture, because such movement will throw the parts of the composite image out of register. It is probably for this reason that camera men avoid as much as possible the use of interior mattes because they reveal with deadly accuracy even the slightest defects in camera manipulation. There is also a use for interior mattes for diffused edge effects by using them in another groove or series of grooves at varying distances between the surface of the film and the lens, but such employment is seldom found as all of these sorts of effects may be obtained much more readily by the use of exterior mattes. An exterior matte is one, usually of larger size than an interior matte, placed in front of the lens at a distance which will give a diffused line of demarcation between the image photographed and that part which is closed off by the matte. When two mattes are used in conjunction in producing one picture, they are so employed that the diffused lines of demarcation between the different exposures fuse into one another and leave no betraying line to reveal exactly where the picture has been split. The amount of this diffusion is determined by two factors. The first factor is the distance from the matte to the lens and the second factor is the dia-

phragm opening, so that if double exposures are made under varying light conditions, the cameraman is confronted with a problem in which he has to equalize a number of different factors. If one exposure is taken in brighter light than the other he may place his second matte closer to the lens to obtain the same degree of diffusion with a smaller diaphragm or he may equalize his exposure by cutting down his shutter opening and place his matte at the same distance from the lens as his first in order to obtain the same degree of diffusion.

In using exterior mattes in place of matching each other exactly as is the case with interior mattes they must overlap one another slightly and the amount of this overlap is determined by the diaphragm opening. For a small diaphragm it is narrow, for a large one it is correspondingly wider. For cloud effects, he has a number of color filters of different hues and of different depths of color and, when using these, he generally, although not always, uses panchromatic negative stock which is sensitive not only to blue light, but to green, yellow and red to which ordinary film stock is comparatively insensitive. With ordinary negative stock only the most pronounced blonde will photograph as being light-haired. With panchromatic stock and a yellow screen he may make the yellow-haired heroine as blonde as he pleases and reduce freckles and facial imperfections to a minimum. With a graduated sky filter, he can give full exposure to objects in a scenic locality and yet retain the details of the beautiful clouds in the background, or bring out the blue distant mountains that would be scarcely visible were they photographed upon ordinary negative stock without a filter. With mattes of yellow celluloid the outer edges of the close-up may be diffused and darkened without suppressing them altogether, by means of mattes mechanically operated by a flexible shaft attached to an elongation of the shutter shaft or other moving part of the camera, one scene may be rolled aside and another take its place as it disappears; not by one dissolving into another, but as if one scene were slid on at one side and by its coming would push the other off at the other side, or, by changing from vertical to horizontal, make one picture go like the scene painted on a theater curtain which rolls up, disclosing the setting behind it.

Optical attachments of small reflecting prisms placed partially before the taking lens permit of double exposure effects being made at one exposure and so forth *ad infinitum*, limited only by the ingenuity and resources of the individual camera operator.

One attachment usually scorned by the average professional is the speedometer for giving the number of frames taken per second. While such an attachment is regarded by many as being superfluous, it should be of considerable value, especially to those operators who are engaged in the production of comedy films of the Mack Sennett type, for many comedy effects depend upon the accuracy with which certain number of pictures per second may be photographed, generally a number considerably less than sixteen per second, and while there are operators who can compete marvelously

with a stop watch in turning to a certain speed per second, they are the exception and not the rule.

Next in our line of attachments we come to the view finder, although we wish to register a protest against classifying the view finder as an attachment or accessory, as it is much too important to be otherwise than an integral part of the camera even if it seldom fulfills the functions for which it is provided. It is of the utmost importance that the view finder show plainly at all times the exact field covered by the lens of the camera and yet it can never do this exactly, because it is not possible to place the view finder so that it will have exactly the same point of view as the taking lens, unless by some as yet unknown device we can utilize the taking lens both as a finder and a photographic objective. The nearest approach to this ideal is perhaps found in the Bell and Howell camera where the lens performs both of these functions, but not simultaneously. This ideal condition being only fulfilled when the image can be viewed through the taking lens at the same time that the picture is being photographed. While this is theoretically not impossible, it is practically so on account of the amount of mechanism that it would be necessary to place in the space already occupied by the shutter to make such a device practical. We can, however, develop the view finder enough so that it is an instrument precise enough for our purposes by placing its objective lens as close as possible to that of the photographic objective and using a compensating device to account for the slight variation between the different view points of the two lenses. Another desirable feature with the view finder is that it should show the image brilliantly, right side up with the image right for right and left for left and not reversed as is usually the case. Negative lenses are not ideal for this purpose as they depend for their accuracy upon the position of the eye being along a certain axis. A view finder should be within the camera box, so that it does not have to be adjusted to the camera after it is taken from the case. It should be plainly and easily visible to the photographer's eye from his natural cranking position. Mr. Akeley, in designing his camera, has paid more attention to the important functions of the view finder than any other camera manufacturer, and yet all must admit that the ideal view finder is yet to be made. Discussion of the problem of an ideal view finder brings us to the problem of the range finder, and by range finder we mean an instrument which performs for the camera exactly the same function that the range finder performs for the artillery—that of measuring the distance from the camera to the object so that the focus may be instantly set without measuring the distance or focusing upon the film or ground glass. Range finders are so well and scientifically worked out that it should be no considerable problem at all to make a simple form of this instrument which would fulfill all of the requirements for cinematographic use. Such an instrument is an integral part of some models of pocket cameras manufactured by the Eastman Company and the manufacturers of moving picture cameras should not lag in following this example. View and range finders are, of course, great aides to the accomplishment of the most efficient use of the photographic objective.

The taking lens is, of course, the most important part of the camera. It must be of the best quality possible, suitably mounted so that it can be accurately focused upon the plane of the film, some modification of the micrometer principle being probably the best and most accurate practical method. Once the scale of distances are calibrated upon a micrometer scale, so that no climatic condition or ordinary wear and tear will derange its adjustment, there should be no further use for focusing devices except to occasionally check results in order to see that no possible accident has happened to its mechanism. Where an accurate calibration of the focusing scale has been made under favorable conditions with a reliable focusing mount, it would be impossible to make any better adjustment by focusing on the thing itself than to measure the distance and set the scale to the proper calibration, no matter how often it may be necessary to inspect the image in the framing aperture for the purposes of lining up or obtaining composition. In an instrument where such accurate work is required as in a motion picture camera, a ground glass for focusing purpose is an absurdity, the coarseness of its surface is much greater than the limit of definition to which it is desirable to adjust the lens. Ground glass should only be used for the determination of the extent of the image within the frame. For focusing the objective a microscope should be provided, so adjusted that its cross hairs or reticule lines will appear in the focal plans; by means of such a microscope the focusing mount should be calibrated. For purposes of viewing the image in the framing aperture some form of reflex attachment is of considerable value. If the mechanism of the camera gives room for the placing of such an attachment between the lens and the film, so much the better, as it renders the opening of the camera and the spoiling of film unnecessary.

As the subject of focusing devices alone is worthy of an extensive paper, it would be unwise for us to dilate here upon the various phases of this subject.

Under the head of attachments, we had also placed in our notes metal fittings. This seems almost superfluous, as there can be no doubt that the film race ways should be made of hard metal capable of receiving and retaining a mirror-like polish upon which there could be no chance of the film being scratched or abraided. Frictional contact with the film should be avoided wherever possible. Static electricity is one of the greatest enemies of the motion picture photographer and friction upon celluloid, as everyone knows, generates static electricity. Here again we must cut our dissertation short as the cause of static, static markings, and static prevention are the subjects for another exhaustive paper, and we dare not intrude this subject upon an already lengthy article. The subject of camera attachments is necessarily a lengthy one and we have attempted in this paper to touch upon only the more salient features in the hope that we may furnish the germ of an idea which may develop in the brain of some of our more able confrères and give to the cinematographic world some noteworthy addition to its many inventions.

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Membership in the Society of Motion Picture Engineers stands for unselfish service to the Industry. Application for membership is by invitation and endorsement. All checks should be made payable to the Society of Motion Picture Engineers.

All receipts are expended directly to promote the objects of the Society and the interest of its members. There are no salaries or emoluments of any kind.

The following are extracts from the By-Laws:

The objects of the Society are: The advancement in the theory and practice of motion picture engineering and the allied arts and sciences, the standardization of the mechanisms and practices employed therein and the maintenance of a high professional standing among its members.

An Active Member is one who is actually engaged in designing, developing or manufacturing materials, mechanisms or processes used in this or allied arts, or who is interested directly in the art.

Any person of good character may be a member in any or all classes to which he is eligible.

Prospective members shall be proposed in writing by at least one member in good standing, and may be elected only by the unanimous vote of the Board of Governors.

All applications for membership or transfers in class shall be made on blank forms provided for the purpose, and shall be accompanied by the required fee.

The entrance fee for all members shall be thirty-five dollars ($35.00). The annual dues shall be fifteen dollars ($15.00), payable in advance before the annual meeting (October of each year). That is, the total fee for the fiscal year, which includes the entrance fees and first annual dues, is $50.00 for all members.

CLASSIFICATION OF PAPERS PRESENTED BEFORE THE SOCIETY UP TO AND INCLUDING THE PITTSBURGH MEETING IN 1919

Cameras, Printing Machines, Camera Equipment, Etc.

Bell—Motion Picture Film Perforation.

Gregory—Motion Picture Cameras.

Gregory and Badgely—Attachments to Professional Cinematographic Cameras.

Carbon Arc Equipment, Etc.

Kunzmann—Carbon Arc for Motion Picture Projection.

Professional Motion Picture Machines

Westcott—Precision: The Dominant Factor in Motion Picture Machines.

Caldwell—Light Intensities for Motion Picture Projection.

Porter and States—Some Considerations in the Application of Tungsten Filament Lamps to Motion Picture Projection.

Roebuck—Sprocket Teeth and Film Perforations and Their Relationship to Better Projection.

Portable Motion Picture Machines

Victor—The Portable Projector; Its Present Status and Needs.

Cook—Advantages in the Use of the New Standard Narrow Width Slow-Burning Film for Portable Projectors.

Motion-Picture Film

Blair—Motion Picture Film in the Making.

Electrical Equipment

Report of the Committee on Electrical Devices—I.

Report of the Committee on Electrical Devices—II.

Incandescent Lamps and Equipment

Dennington—The Projection of Motion Pictures by Means of Incandescent Lamps.

Dennington—Incandescent Lamps for Motion Picture Projection.

Studios and Laboratories

Allison—Standards of Exposure.

Mayer—Artificial Light in the Motion Picture Studio.

Allison—Standardization of Motion Picture Industry in the Ideal Studio.

Mott—White Light for Motion Picture Photography.

O'Brien and Campe—Selection of Proper Power Equipment for the Modern Studio.

Architectural Subjects

Smith—Off-set Projection.

Jenkins—The Motion Picture Projection Room.

Richardson—The Projection Room and Its Requirements.

Optical Research

Jenkins: Condensers: Their Contour, Size, Location and Support.

Report of Committee on Optics

Corey—Optical Requirements of Motion Picture Projection Objectives.

Jenkins—Condensers.

Kellner—Function of the Condenser and the Projection Apparatus.

Richardson—Some Phases of the Optical Systems of the Projector.

Gage—Condenser Design and Screen Illumination.

Story—Preliminary Measurements of Illumination in Motion Picture Projection.

Colored Photography

Kelly—Natural Color Cinematography.

Kelly—Adding Color to Motion.

Miscellaneous

Richardson—Theory vs. Practice as Applied to Standardization and Some of the Things to be Considered as Proper Subjects for Standardization.

Burrows—Fundamentals of Illumination in Motion Picture Projection.

CLASSIFIED MEMBERSHIP LIST

Manufacturers of Cameras, Printing Machines, Camera Equipment, Etc.

Akeley, Carl A. Akeley Camera, Inc., 250 W. 49th St., New York City.

Bell, Don J., 1202 Third St., San Diego, Calif.

Gregory, Carl L., 604 W. 125th St., New York City.

Jenkins, C. Francis, 712 11th St., N. W., Washington, D. C.

Nelson, E. W. Wilart Instrument Co., 13 Rose St., New Rochelle, N. Y.

Manufacturers and Dealers in Supplies for the Theatre

Brown, Nat I., 1600 Rhode Island Ave., Washington, D. C.

Cromelin, Paul H., Inter-Ocean Film Corp., 220 W. 42nd St., New York City.

Cudmore, H. H. Argus Lamp and Appliance Co., Sloan Bldg., Cleveland, Ohio.

Edwards, H. T. United Theatre Equipment Corp., 1604 Broadway, New York City.

Hastings, R. G. Motion Picture Apparatus Co., 110 W. 32nd St., New York City.

Hallberg, J. H., 1604 Broadway, New York City.

Lang, C. J. Lang Mfg. Co., Olean, N. Y.

Perkins, Geo. F., 497 Phillips Square, Montreal, Canada.

Rembusch, Frank. Rembusch Screen Co., Shelbyville, Ind.

Rabell, Wm., 729 Seventh Ave., New York City.

Manufacturers of Studio Supplies

Hubbard, Wm. C. Cooper-Hewitt Electric Co., 120 Broadway, New York City.

Mayer, Max. Wohl & Co., 211 Fulton St., Brooklyn, N. Y.

Manufacturers of Carbon and Carbon Arc Equipment

Kunzmann, Wm. C. National Carbon Co., Box 400, Cleveland, Ohio.

Mott, W. R. National Carbon Co., Research Laboratories, Cleveland, Ohio.

Speer, J. S. Speer Carbon Co., St. Marys, Pa.

Manufacturers of Professional Motion Picture Machines

Brockett, Paul, c/o C. Francis Jenkins, 712 11th St., Washington, D. C.

Farrell, John W. Master Machine Co., 2638 Park Ave., New York City.

Jenkins, C. Francis, 712 11th St., N. W., Washington, D. C.

Porter, E. M. Precision Machine Co., 317 W. 34th St., New York City.

Robin, J. E., 729 Seventh Ave., New York City.

Roebuck, A. C. Enterprise Optical Co., 564 W. Randolph St., Chicago, Ill.

Smith, Will C. Nicholas Power Co., Inc., 90 Gold St., New York City.

Manufacturers of Portable Motion Picture Machines

Cook, Willard B. Pathescope Co., Aeolian Hall, New York City.

DeVry, H. A., 1248 Marianna St., Chicago, Ill.

Davidson, L. E. United Projector & Film Co., 69 W. Mohawk St., Buffalo, N. Y.

Gundelach, A. E. DeVry Corp., 1248 Marianna St., Chicago, Ill.

Redpath, N., 156 King St., W. Toronto, Ont., Canada.

Victor, A. F., Victor Bldg., Davenport, Ia.

Manufacturers of Film

Blair, G. A., Eastman Kodak Co., Rochester, N. Y.

Manufacturers of Electrical Equipment

Bateholtz, C. F. General Electric Co., Schenectady, N. Y.

Campe, H. A. Westinghouse Electric Mfg. Co., East Pittsburgh, Pa.

Hertner, J. H. Hertner Electric Co., W. 114th St., Cleveland, Ohio.

Hallberg, J. H., 1604 Broadway, New York City.

Lee, R. L. Domestic Engineering Co., Dayton, Ohio.

Moulton, J. C. General Electric Co., 120 Broadway, New York City.

Richards, Thomas T. Wagner Electric Co., 6400 Plymouth Ave., St. Louis, Mo.

Wible, Harvey M. Westinghouse Electric Mfg. Co., East Pittsburgh, Pa.

Manufacturers of Incandescent Lamps and Equipment

Burnap, Robert S. Research Laboratories, Edison Lamp Works, Harrison, N. J.

Cudmore, H. H. Argus Lamp & Appliance Co., Sloan Bldg., Cleveland, Ohio.

Dennington, A. R. Westinghouse Lamp Co., Bloomfield, N. J.

Egeler, C. E. National Lamp Works, Nela Park, Harrison, N. J.

Kroesen, J. C. Edison Lamp Works, Harrison, N. J.

Livingston, M. H. 310 Liberty St., Peoria, Ill.

Porter, L. C. Edison Lamp Works, Harrison, N. J.

States, Wm. M. Edison Lamp Works, Harrison, N. J.

Studios and Laboratories

Anderson, Carl, 21 Douglaston Rd., Douglaston, L. I.

DePue, O. B., 7460 Sheridan Rd., Chicago, Ill.

Joy, Henry, 670 Avenue E, Bayonne, N. J.

Kessel, N., Main St. & Linwood Ave., Fort Lee, N. J.

Kelley, Wm. V. D. Prizma, Inc., 71 W. 23rd St., New York City.

Miles, Herbert. Kine Cartoon Film Corp., 220 W. 42nd St., New York City.

Murphy, E. F. Universal Film Mfg. Co., Fort Lee, N. J.

Rothacker, W. R. Rothacker Film Mfg. Co., 1339 Diversey Parkway, Chicago, Ill.

Rossman, Earl W., 1630 St. Nicholas Ave., New York City.

Urban, Charles, 71 W. 23rd St., New York City.

Wescott, W. B. Technicolor Film Corp., 9 Harcourt St., Boston, Mass.

Architects

Braun, Wm. T., 155 North Clark St., Chicago, Ill.

Kinsella, Edw. B., 39 W. 37th St., New York City.

Optical Research

Gage, H. P. Corning Glass Works, Corning, N. Y.

Kellner, Dr. Herman. Bausch & Lomb Optical Co., Rochester, N. Y.

Story, Dr. W. E. General Electric Co., Schenectady, N. Y.

Turner, H. H. Gundlach Manhattan Optical Co., Rochester, N. Y.

Wollensack, Andrew, Wollensack Optical Co., Rochester, N. Y.

Colored Photography

Rossman, Earl W., 1630 St. Nicholas Ave., New York City.

Wescott, W. B. Technicolor Film Corp., 9 Harcourt St.. Boston, Mass.

Consulting Projection and Electrical Engineers

Burrows, R. P., 209 Sloan Bldg., 823 Prospect Ave., Cleveland, Ohio.

Bragdon, E. L. Motion Picture News, 729 Seventh Ave., New York City.

Jenkins, C. Francis, 712 Eleventh St., N. W., Washington, D. C.

Richardson, F. H. Moving Picture World, 516 Fifth Ave., New York City.

Robin, J. E. 729 Seventh Ave., New York City.

PRESIDENT'S ADDRESS

The Society of Motion Picture Engineers is now a well-established organization. During the three years of its existence, notwithstanding the hard struggle which we have experienced during an exceedingly trying period, we have, at all times shown the spirit of progress which has resulted in a successful organization. The success with which we have met has not been due to individual efforts, but rather to the united efforts of our members.

I had hoped to be able to present some statistics of the Motion Picture Industry, in order that I could more strongly impress upon you the magnitude of the industry which your considerations and standardizations will ultimately affect. While no exact figures are available on films now produced in the United States, an estimate has been made that the production exceeds 1,000,000,000 feet, with a valuation of approximately $40,000,000.00, of which three-quarters covers photoplays, the other one-quarter being divided among travelogue, news service, comedy and industrial films. These figures cover only the films produced and do not cover the investment in studios, laboratories, factories, exchanges or theatres. Were we able to get an approximate financial estimate involving the Motion Picture Industry as a whole, we would be able to more thoroughly realize the burden we are called upon to assume.

The Society is the technical clearing house of the Motion Picture Industry. Our membership is composed of men who are each and every one expert in his own line and, because of this, we meet periodically for the purpose of discussing the various problems peculiar to the industry.

Motion pictures have rightfully been called the universal language. In the past, their use has been confined largely to entertainment, but at the present time there is a healthy natural tendency towards their use for educational and research purposes.

In view of the work which we are called upon to do, I do not believe that our Society is receiving the proper recognition from the industry. Just how this recognition can be acquired and what form it should take, I shall not now even venture specific suggestions, but I do realize that we should be in closer relationship with the leaders of the industry who mainly are responsible for its advancement because we are all aiming towards the same objective—that of producing better pictures by the most effective methods.

I again wish to impress upon you that our Committees are not sufficiently active. There does not seem to be sufficient co-operation and exchange of ideas. To take care of this situation, beginning with this meeting, we are going to set aside a definite period during our sessions when the chairman of each committee can get together with the members of his committee to prepare a report for presentation to the Society. This is indicated in the program of the meeting, copies of which you have, and to further assist, a list of the personnel of the various committees will be posted in the rear of this room.

One of the subjects which should receive our most serious consideration is that of the presentation of papers. I shall not anticipate nor supplement the report of the Committee on Papers, however I do feel that all of the Society should be sufficiently informed on some subject to individually present a paper on some phase of the industry. In the past, most of the papers have been prepared and presented by a few faithful members, while the rest of the members are content to sit back and listen to the presentation and discussion and thereby benefit by the experience of others without contributing anything themselves. Consequently, the work of the Committee on Papers has been decidedly difficult and this is a condition which should be corrected without delay. This committee should be in a position to select what papers should be presented, instead of having to write letters of request for members to prepare papers. Furthermore, I believe that the papers should originate through the various standing committees, which, when they meet, should decide on what subjects should be covered by a paper and then certain members of that committee should be designated to prepare the papers. When this information is placed in the hands of the Committee on Papers it can very easily line up the schedule long before the time of the meeting. The manuscript can then be submitted and advance copies can be printed and sent to the chairmen of the various committees who can designate certain members to discuss the paper. In this way, we shall obtain the maximum result. To assist those who are preparing papers, the Committee on Papers has prepared a little booklet for their guidance.

I also wish to touch on the work of our Committee on Publications. Our semi-annual proceedings are now being distributed promptly and because of the publicity of the two leading trade magazines, we are receiving a large number of orders for single copies. We have a good supply of all copies of the proceedings except Vol. I, and we have been offering these, unbound, for $1.75 per set to projectionists, with good results. Our first bound volume is now being distributed, the price being $1.50 to members, to cover the cost of binding, and $5.00 to non-members. About half of our membership have ordered copies and I wish the others would place their orders immediately with Mr. Smith, Mr. Jenkins or the writer. There are only about 40 copies still available. The value of this volume is inestimable because there is absolutely no other book which contains such a fund of technical information of the Motion Picture Industry.

After talking with several members of the Society I believe it is the general opinion that some consideration should be given by the Society relative to increasing the initiation fees and membership dues. I feel also that the price which we charge for our transactions is too small, as it is not even sufficient to cover the cost of publication. I trust that this matter will receive your serious consideration during this session.

The foregoing embodies about all that I feel it is necessary to say but as a last word in concluding, I desire to leave with you one thought more vital than all others; namely, that not only does the success of this Society, as a whole, depend upon the collective activities of its members but also that each member, to acquire the highest benefit for himself and others, should take an active part in this collective effort. From all sides, I have met with most cordial encouragements and assistance from those who have given of their time, without any recompense and for this I thank you most cordially. The meeting is now yours.

PRELIMINARY MEASUREMENTS OF ILLUMINATION IN MOTION PICTURE PROJECTION

By W. E. Story, Jr.

First efforts to compare accurately the total illumination in motion picture projection with different optical arrangements, led to such improbable conclusions as to point to errors of observation so large as to render the required comparison unsatisfactory. The problem is to compare the quantities of light falling on the objective lens through a standard motion-picture aperture, with different sizes of source and objective; with different condenser systems, and with different distances between the various components. The reason for considering the light falling on the objective rather than on the screen is that the efficiency of the objective depends on its design, and with the large number of designs now at hand, the addition of this complication seemed inadvisable—especially as this problem belongs to the lens designer alone, and has nothing to do with the relation of the different parts of the projection apparatus. Accordingly, for the objective lens there was substituted a dummy objective, that is, a circular hole in a brass plate, this hole being of the size of the assumed effective diameter of the lens and the plate being at a distance from the aperture equal to the assumed focal length of the lens. Immediately behind this dummy objective was put a piece of flashed opal glass considerably larger than it, and 4 inches from this glass another similar one—a connecting brass tube blocking out stray light between. The illumination of the center of this second opal glass by the first is very even, and is proportional to the total light flux delivered by the rest of the optical system to the objective. The even illumination of this second opal glass was measured by a photometer mounted directly behind it, and built in as one assembly with the opal glasses, the dummy objective, and the aperture plate. The aperture plate was 5½ inches in front of the dummy objective; the 5½ inches corresponding to the focal length of an objective frequently met in practice. An arrangement was made for changing the size of the objective opening.

The above assembly was mounted on the rider of an optical bench—another rider carried the condenser, and a third, the source and its housing. To obtain a source of uniform brilliancy and variable size an opal glass was strongly lighted from behind. Two thin metal shutters slid across the front of this opal glass in such a way that an illuminated square of any desired size and with two of its sides vertical served as the light source. The shutters lay close to the opal glass to give the same source for all points of the condenser.

The method of procedure was as follows:

The illumination of the opal glass source was carefully kept constant at all times. With a given source side, source-condenser distance (which for convenience we shall call d_1) and objective,

the distance from condenser to aperture plate (d_2) was varied inch by inch, and the corresponding photometer readings taken—two readings being taken at each position. In this way curves were obtained for a large number of different conditions. Sample curves are shown in Figs. 1, 2, 3, 4.

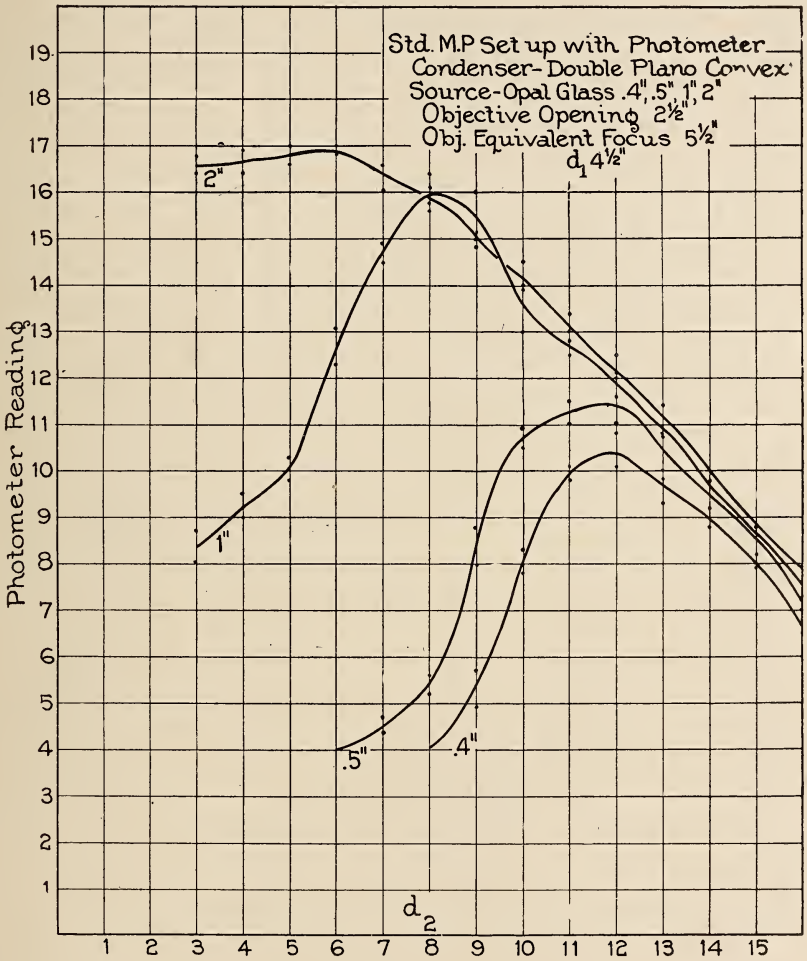


Fig. 1

The crossing of the curves in (1), (2) and (4) could be explained only by some error in observation. Check curves at different times did not give the same results. The most probable source of error was the photometer. Accordingly, it was decided to try a photoelectric cell as a means of measuring the total light flux.

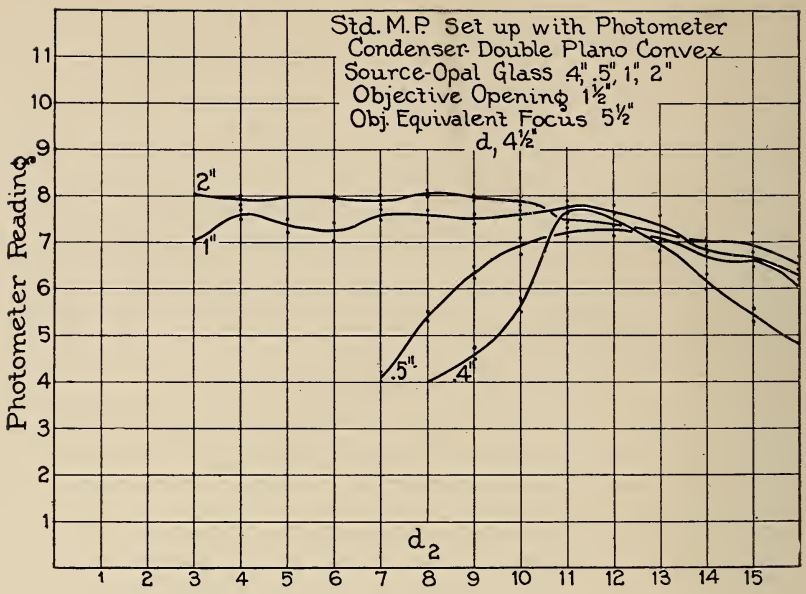

Std. M.P. Set up with Photometer
Condenser- Double Plano Convex
Source-Opal Glass .4", .5", 1", 2"
Objective Opening 1½"
Obj. Equivalent Focus 5½"
d, 4½"
Photometer Reading
2"
1"
.5"
.4"
d2
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
1 2 3 4 5 6 7 8 9 10 11

FIG. 2

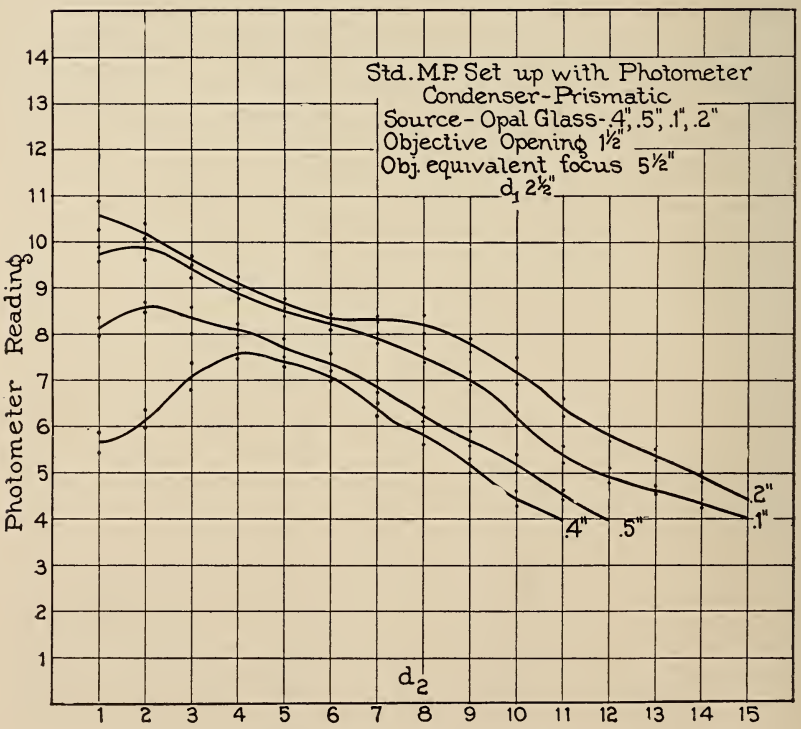

Std. M.P. Set up with Photometer
Condenser-Prismatic
Source- Opal Glass-.4", .5", .1", .2"
Objective Opening 1½"
Obj. equivalent focus 5½"
d, 2½"
Photometer Reading
.2"
.1"
.4"
.5"
d2
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15
1 2 3 4 5 6 7 8 9 10 11 12 13 14

FIG. 3

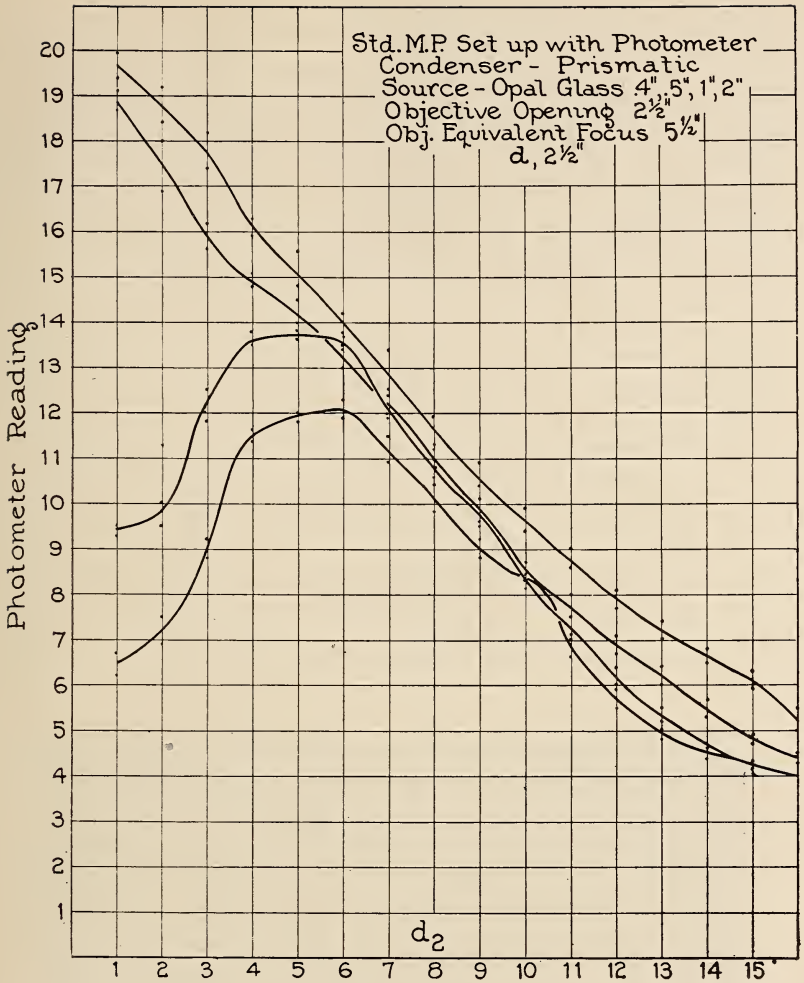


Fig. 4

The potassium photoelectric cell at hand was not sufficiently sensitive to be used in connection with all the opal glasses used with the photometer. Accordingly, an incandescent filament was substituted for the variable source. This filament consisted of four similar helices side by side, each of .089 inches diameter, and .48 inches long, and the spaces were .038 inches wide. This gives a uniform source .48 inches high by .47 inches broad. The increase of light obtained by this means was still not sufficient to permit of the use of the photoelectric cell. The second opal glass beyond the objective was next removed, and the cell put in its place, being so arranged that as much of the potassium surface as possible could view the whole aperture opening. A suitable deflection was now obtained with the galvanometer.

In series with this cell there was a constant potential of 72½ volts, and a reflecting galvanometer of a sensitivity of 3.98 x 10^{-9} amps. In place of the customary scale, a narrow horizontal slit was cut in a box in which a photographic plate moved up and down directly behind the slit. This motion was regulated by a cable and pulleys to be one-half the horizontal motion of the aperture-objective assembly. As d_2 is changed then, the light reflected in the galvanometer mirror will trace out a curve on the plate, the abscissae of which curve, if the zero point is correctly chosen, are one-half the distance d_2, and the ordinates the galvanometer deflection.

The first plates made were run both ways on each setting, giving a double curve. It was found, however, that under normal conditions, these two curves checked within 2 per cent. As this is about the limit of difference detectable with the eye, it was considered sufficient to run but a single curve for each arrangement. Accordingly, a number of curves of different arrangements were run on the same plate for comparison, running the plate up and down (that is, increasing and decreasing d_2 alternately for each successive curve), and making the change of arrangement at the end of each curve. At the beginning of each curve the reading of the galvanometer was photographed with an opaque slide in front of the aperture and through these marks the zero line of the light flux was drawn. During the progress of the first curve

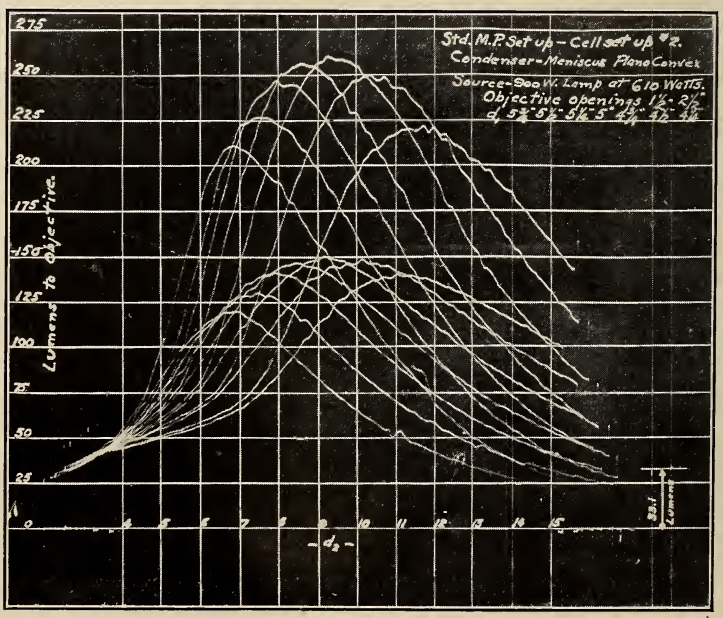


Fig. 5

run on each plate an open lamp in front of the plate slit was flashed as the aperture plate crossed each inch mark, thus marking the d_2 scale photographically.

A sample plate is shown in Fig. 5.

The seven higher curves are with a 2½ inch objective and source-condenser distances d_1 decreasing by ¼ inch steps from 5¾ inches as the abscissae of the maxima increase. The lower curves are with a 1½ inch objective and the same d_1's as the other group.

These curves of course indicate the sharpness of setting necessary for d_2 in order to get within any given proportion of the maximum light available for this particular value of d_1.

The loci of the maxima for the two objectives are given in Fig. 6.

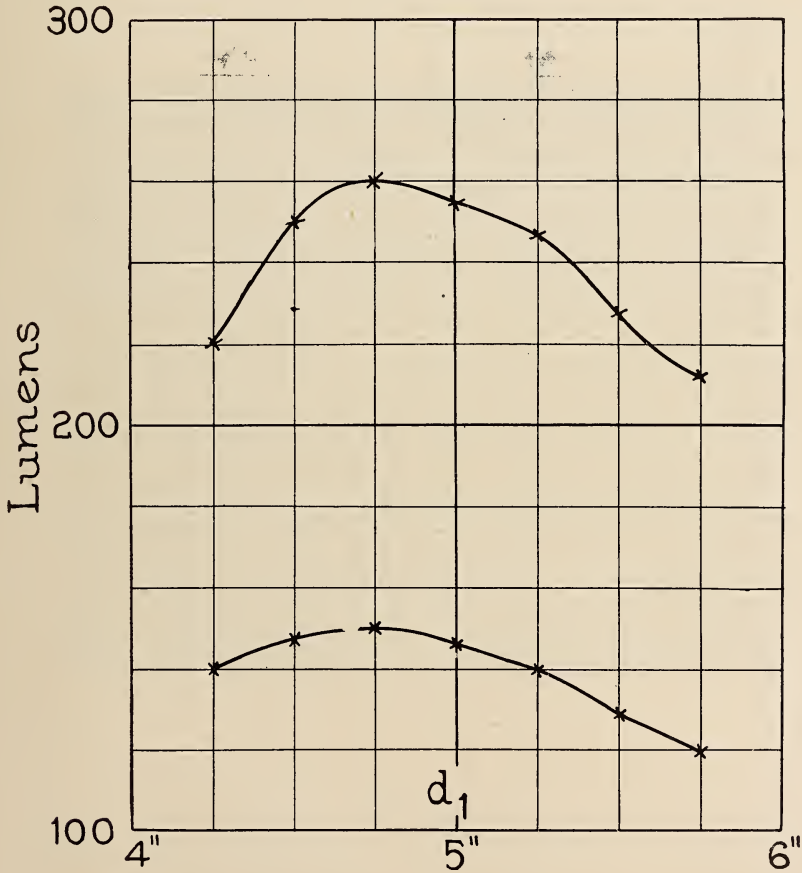


Fig. 6

The abscissae are the values of d_1 for the curves of Fig. 5 and the ordinates are the deflections of the corresponding maxima. These two curves indicate the sharpness of setting of d_1 necessary for any required approach to the maximum light obtainable. Latitude of position of the different parts is of course very desirable for any arrangement and may be the deciding factor in the choice of lenses.

To determine whether the galvanometer deflection was proportional to the quantity of light passing the objective, curves were made without condenser or aperture, and the abscissae representing the distance from the source to the objective. When this distance is large, the amount of light falling on the opal glass is of course inversely proportional to the square of this distance. Also for large distances the amount of light passing objectives of different sizes, will be proportional to the area of their openings.

Fig. 7 shows curves made with a 2½ inch and 1¾ inch dummy objective.

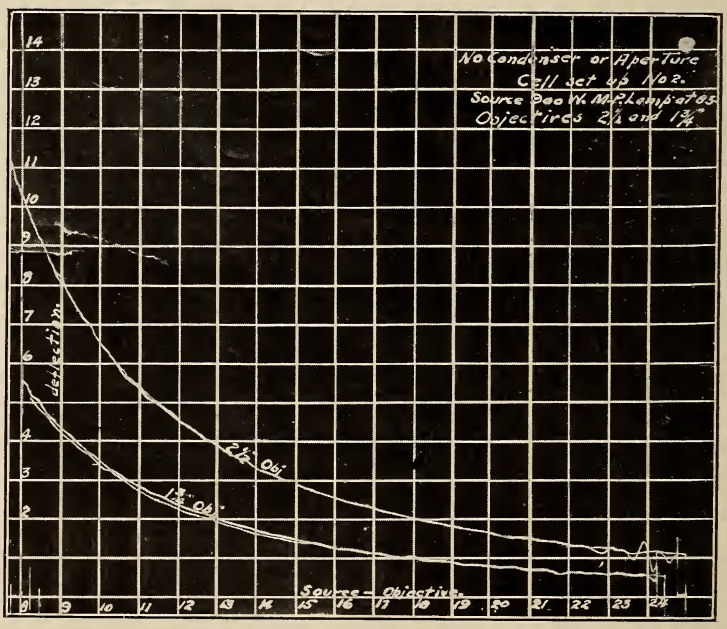


Fig. 7

In the table below (Fig. 8) column I indicates the distances of the dummy objective from the source. Columns II and III give the product of light received on the 1¾ inch and 2½ inch objectives by the square of the distance of the objectives from the source, and column IV gives the ratio of the light passed by the two lenses at any given distance.

Dist. 2 I d	d^2 x defl. II 1¾ Obj.	d^2 x defl. III 2½ Obj.	IV* III/II
8	176	328	1.86
9	173	324	1.87
10	173	326	1.87
11	170	327	1.92
12	167	327	1.95
13	169	330	1.95
14	165	328	1.98
15	165	327	1.98
16	164	328	2.00
17	167	334	2.00
18	167	329	1.96
19	163	332	2.06
20	156	331	2.12
21	152	337	2.28
22	151	324	2.14
23	156	331	2.18
24	162	337	1.94
	163	324	
		331	
		315	

*With a new cell especially designed for this work, it is hoped values in column IV more nearly 2.04 will be obtained.

The constancy of the values in columns II and III shows the deflection to be proportional to the light through an objective of a given size, and the agreement of the values in column IV with 2.04, the ratio of the objective areas, shows the deflection to be almost independent of the size of the objective as long as the total quantity of light transmitted is the same. Columns II and III are plotted in Fig. 9.

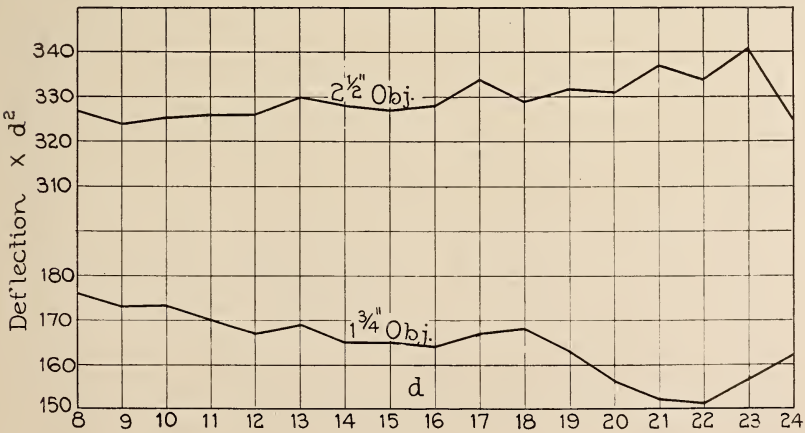


Fig. 9

Those deflections in the low end of the curves are so strongly affected by inaccuracies of the zero line as to be very doubtful. This inaccuracy probably also accounts for the gradual decrease in the curve of the 1¾ inch objective. Large deflections, those in which we are most interested, will, of course, be influenced but little by these variations of the zero.

A slight change in the sensitivity of the present photoelectric cell was noticed from one day to another. To make allowance for this before each plate was made, a standard lamp was set at such a constant distance from the aperture that all the light passing through it passed through the objective as well, and then the deflection due to this known amount of light, photographed. From these marks the scale of the ordinates denoting lumens was calculated. Due to differences of absorption and source temperature, this scale of course must not be regarded as accurate, but merely as an approximation.

An incandescent filament was photometered at different efficiencies, and the maximum horizontal candle power plotted against the watts consumed. This same filament was lighted at a convenient distance in front of the dummy objective, and the deflection-watts curve plotted.

Fig. 10 shows these two curves—the ordinates of the second

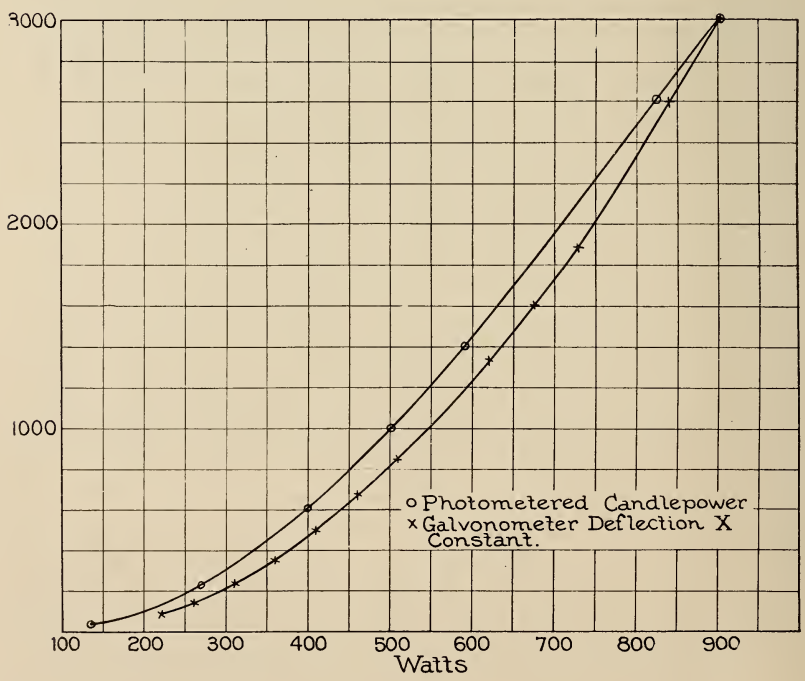


Fig. 10

being multiplied by such a constant as will make the 900 watt points of the two curves coincide.

As might be expected, these two curves cannot be made to coincide by any choice of scales, since the maximum energy is in the shorter wave-lengths the higher the brilliancy, and the eye has its maximum sensitivity in the yellow, while the photoelectric cell is most sensitive in the blue end of the spectrum. Since in motion picture projection the eye is the judge of brilliancy lights of different colors cannot be accurately compared by the cell method. The curves for any given condenser and source brilliancy are comparable, but when curves made with different sources or absorbing media in the system, are in question, corresponding points in the two set-ups must be compared by means of a photometer. If the readings of one set-up be then multiplied by the factor thus obtained, the curves will be directly comparable. At present we are using a photometer as a final judge between different systems, but for determining the most advantageous arrangement for any particular system the photoelectric cell seems to offer a far quicker and more accurate method.

Of course, the method of measuring the light delivered by an optical system says nothing about the distribution on the screen. This will have to be determined separately, and probably cannot be determined by any method that does not depend on direct observation by the eye. The method described above is to be applied only after the general limits, through which the optical arrangement may be varied without causing too uneven a distribution on the screen, have been determined.

In a following paper we hope to give some comparisons of different optical systems in common use, as well as those giving the most light at present obtainable.

SELECTION OF PROPER POWER EQUIPMENT FOR THE MODERN MOTION PICTURE STUDIOS

By H. F. O'Brien and H. A. Campe

Synopsis: This paper cites most of the factors that must be considered in making the proper selection of power equipment for the Motion Picture Studios. After reviewing the more important factors, suggestions are made regarding the type of equipment that should be selected to produce the best possible results under given conditions.

OUTLINE

I. Introduction.
II. Two-wire versus three-wire distribution.
III. Classification of apparatus.
Description—Discussion—Criticism.
1. Rotary converter.
1a—Two-wire.
1b—Three-wire.
2. Motor-generator set.
2a—Two-wire—two unit.
2b—Three-wire
Three-wire generators.
Two-wire generators—Balance set.
Two—Two-wire generators.
IV. Conclusions.

INTRODUCTION

The new studios have decided from either their own experience or that of others, that it is an economical proposition for them to have their studios so equipped that a sufficient supply of electrical energy will be available for the proper illumination of their stages. During the past two years, there has been a general tendency towards using more artificial illumination in the studio, almost to the total exclusion of sun light. During this period, there has also been a great tendency to unify the electrical installations so the same nature of current is used throughout, irrespective of the nature of supply current. Some studios, particularly the new ones, in and about New York are being equipped with direct current exclusively.

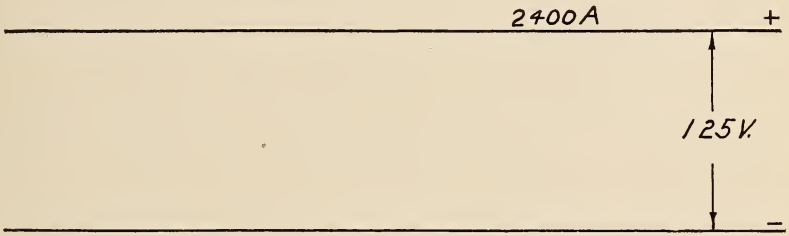
The large power companies, except in restricted zones, are making the extensions of their power distribution system, alternating current, and in fact, have replaced most of their old direct current distribution systems with alternating current. These tendencies have forced most all of the studios to install their own substations for converting the alternating current supply to direct current.

Except in certain portions of New York City, there are very few studios located where they can obtain sufficient direct current to meet their requirements, but nearly every studio is located where

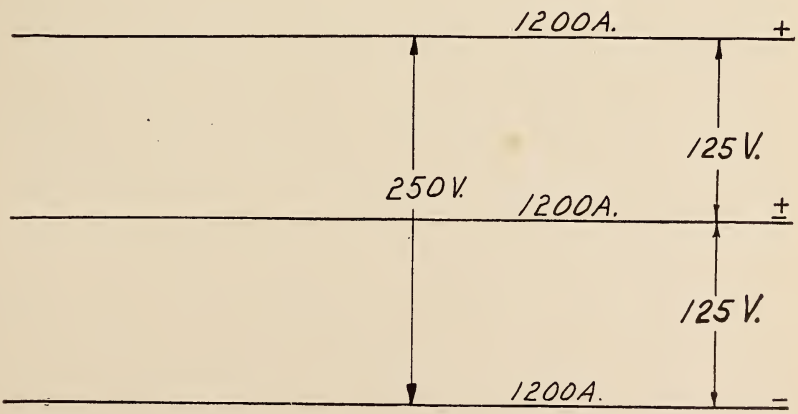
alternating current can be purchased in sufficient quantity so that the easiest and most economical means of obtaining direct current is to purchase alternating current power and convert it. Converting apparatus will be described later in this paper.

II. TWO-WIRE VS. THREE-WIRE DISTRIBUTION

A two-wire system is one in which a single voltage is generated and a three-wire system is one in which two separate single equal voltages are transmitted which may be additively combined to produce a third voltage. With the two-wire system, as the name implies, only two wires are required. With the three-wire system, three wires are required for main distribution. On a three-wire distribution system, one wire known as the "neutral" is common to both the equal voltage circuits and carries only the unbalanced current in the system. By unbalance is meant the difference in amperes flowing in the two equal voltage circuits. The other two wires, known as the outside wires, carry their proportional part of the total current in the system, whether balanced or unbalanced.



2 Wire D.C. System.



3 Wire D. C. System.

As a general rule, and particularly where heavy currents at low voltages must be handled, it is desirable from a standpoint of copper economy to install the three-wire distribution system. Most studio electricians have found that the three-wire system has many advantages. For example, a two-wire system handling 300 KW., at 125 volts, would require that each side of the line be of sufficient capacity to carry 2400 amperes. This would call for 4,000,000 CM. of copper for each side, or 8,000,000 CM. of copper per circuit. Such an installation would require very large conduit and would be very difficult to install.

If the same load were to be handled on a three-wire system, each conductor would be required to handle 1200 amperes which would call for 2,000,000 CM. in copper and as most code regulations demand that the neutral or third wire be the same size as the two outside wires, it would take three conductors, of 2,000,000 CM. each. Thus, in this case, 6,000,000 CM. of copper are required for three-wire distribution where it is found that 8,000,000 CM. of copper would be required to handle the same load on a two-wire system.

It is evident, from the above example, that a 25 per cent. saving in copper would be effected by using a three-wire instead of a two-wire system. This saving would be somewhat further increased because of lower installation costs. There is only one argument against the use of a three-wire system and that is the proposition of unbalancing the system. This subject will be discussed under Classification of Apparatus.

III. CLASSIFICATION OF APPARATUS

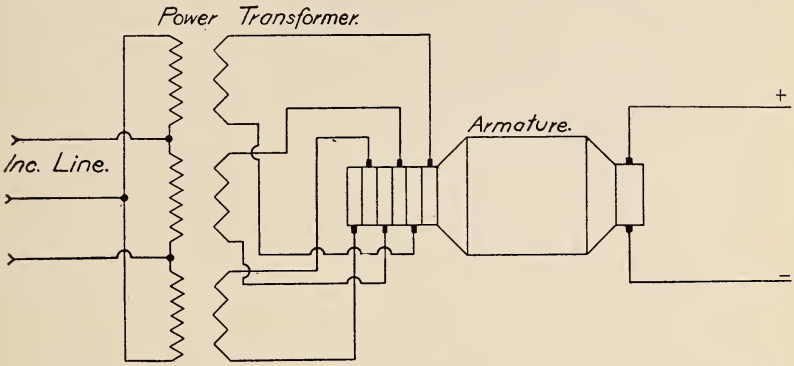
The characteristics of the incoming power supply with respect to voltage and frequency regulation will determine largely the type of equipment to be used. It would be difficult here to make suggestions that would satisfactorily cover each and every installation but the suggestions given later in this paper should, at least, act as a good guide.

In the case of selecting additional apparatus for the studio it is wise to consider equipment similar in characteristics to the apparatus already installed, as undoubtedly, parallel operation of units will be desired. In other words, it would not be good engineering practice to parallel rotary converters with motor-generator sets unless such a scheme would be recommended by a reputable engineer who, after making a careful study of the conditions, would guarantee satisfactory operation.

There are only two practical means of converting alternating current to direct current in the capacity required in the studio; namely, rotary converters and motor-generator sets. We will first consider some of the inherent characteristics of each, for these characteristics determine which type of apparatus will best be suited for the installation.

1. Rotary Converters. The rotary converter is a single-unit machine which received its power from the incoming alter-

nating current line and furnishes direct current at the desired voltage. Power is supplied to the rotary through a bank of transformers having primary or high-tension windings designed for the voltage of the power circuit. The low tension or secondary windings are designed, in the case of a three-phase rotary, to give a voltage of .62 times the direct current voltage desired. In the case of a six-phase diametrically connected rotary, this ratio is .72.

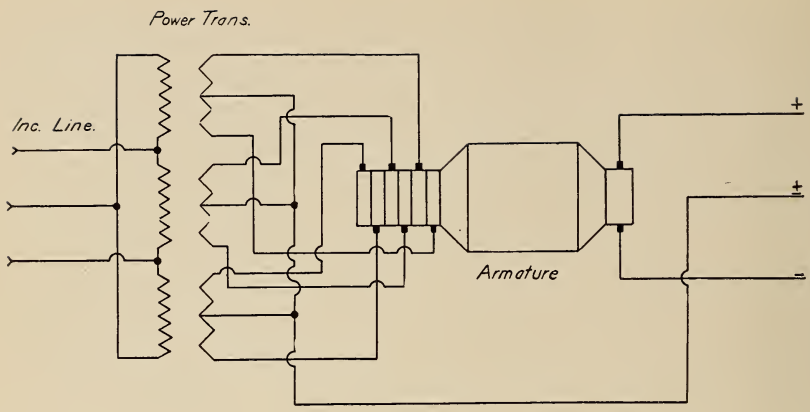


2 WIRE SYNCHRONOUS CONVERTER.
2 WIRE SYSTEM.

1a. Two-Wire Rotaries. While the rotary may be considered ideal, it can only be recommended for studio's application under ideal conditions and these should be very carefully investigated both for present and future possibilities. Inasmuch as the direct-current voltage of a rotary varies in direct proportion to the change of either the voltage or frequency of the circuit supply, the rotary should only be selected for use on a power line having ideal voltage and frequency regulation, since constant direct-current voltage is essential for correct studio illumination. Graphic charts should be taken covering a period of at least two weeks to definitely determine whether or not the conditions of the power circuit will permit this application. The variation in either voltage or frequency should not exceed 3 per cent.

1b. Three-Wire Rotaries. If it is desired to obtain a three-wire direct-current system using a rotary this can be accomplished by bringing out the neutral point of the transformers which would be interconnected star. The maximum balance that is allowable under such conditions is 25 per cent. of full load current.

Either two or three-wire rotaries can be paralleled on the same bus without difficulty. It is understood, of course, that each rotary requires its own bank of transformers for the alternating-current end and therefore the cost of the complete installation will closely approximate the cost of a motor-generator installation.



3 WIRE SYNCHRONOUS CONVERTER.
3 WIRE SYSTEM.

The new Thomas Ince Studios at Culver City, California, are securing excellent results from their 250 KW. three-wire rotary installation. In the case of this installation, constant voltage on the 2200-volt power circuit is obtained by means of an induction regulator installed in the sub-station of the Southern California Edison Company.

2. Motor-Generator Sets. Motor-generator sets are built in several combinations with respect to the driving motor. The only type we need to consider for studio applications are those driven with alternating-current motors. In this classification we will consider sets driven by squirrel cage induction and synchronous motors.

As induction motors have generally been used, we will consider the characteristics of this type first. The induction motor has what is commonly known as "Slip." By this we mean that the motor will slow down slightly with an increase of load. As the generator is directly connected to the motor, it will correspondingly decrease in speed, resulting in a slight drooping characteristic in the generator or direct-current voltage. The speed of an induction motor is practically constant under constant load conditions, from 80 per cent. normal voltage to slight over-voltage. This characteristic is a point in its favor where a studio is located where there is slight voltage fluctuations on the incoming power line. Induction motors only should be considered in the smaller sizes ranging up to 100 KW. capacity, except in special cases. The power factor of the squirrel cage induction motor will vary from about 74 per cent. at one-quarter load to about 92 per cent. at full load. These motors are always started with auto transformers in the starting circuit so that the starting current is not excessive. Normally, the starting

current will run from 1.3 to 1.5 times full load current which should not be objectionable to the power companies.

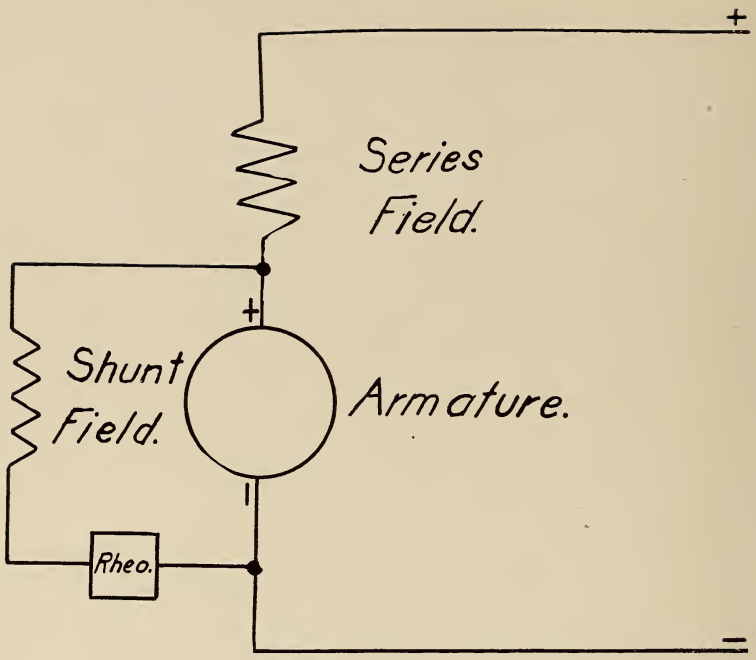
Modern synchronous motors have a squirrel cage or damper winding in the rotating element, so that they have practically all the good starting characteristics of an induction motor. In addition, they can be wound to operate at unity power factor at light loads. The speed of a synchronous motor depends only upon the frequency of the power circuit and is not affected by load variation. As most of the large power companies keep the frequency within a 3 per cent. variation, it can readily be seen that a synchronous motor would be very desirable inasmuch as it operates at constant speed, resulting in constant voltage at the generator terminals. Some electricians imagine that a synchronous motor is a piece of apparatus requiring expert attention and care. Possibly they may have had some unpleasant experiences with the older obsolete types, but the modern synchronous motor is as simple to handle as an induction motor. It starts as an induction motor and comes up to synchronous speed readily so that it can be connected to the line without difficulty.

Let us next consider the different types of direct-current generators and their characteristics. There are two general types of generators; namely, shunt-wound and compound-wound. The shunt-wound generator gives a variable voltage characteristic under variable load conditions, whereas, the compound-wound generator, when properly adjusted, will give a constant voltage characteristic over a wide variation in load. Obviously, we will consider only the compound-wound generator for studio service.

2a. Two-Wire Generators. The simplest form of a generator is a single-unit two-wire type, in which a single voltage only is generated. The voltage produced by this type of generator can be varied within a limited range by means of the shunt field rheostat.

2b. Three-Wire Equipments. There are three practical means which may be employed through the use of motor-generator sets to produce direct-current supply for three-wire systems; namely, three-wire generators, two-wire generators with balancer set, and 2 two-wire generators of equal voltage permanently connected in series. A short description of each will follow.

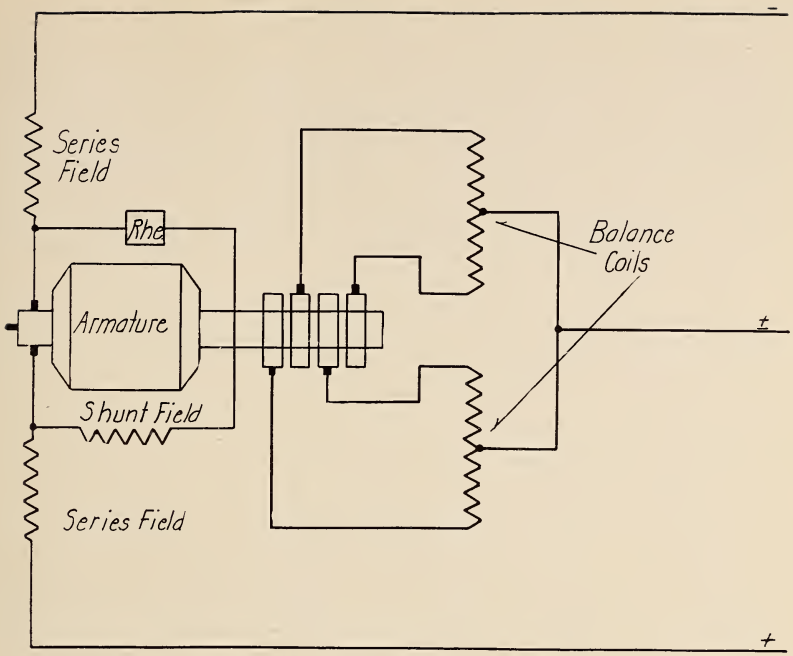
Three-Wire Generators. The single unit three-wire generator is simply a modification of the two-wire generator in which certain internal connections, together with balanced coils mounted externally or internally, produce a neutral point, which, with the main generator terminals, gives a double voltage or a three-wire system. The commercial three-wire generator is built to take care of from 10 to 20 per cent. unbalanced condition, which means that one side of the three-wire system may be loaded 10 to 20 per cent. more than the other side without involving difficulties. In studios where the load is being constantly shifted as the lamps are plugged in on various circuits, it is practically impossible to keep the unbalance within the limits required by three-wire generator design, due



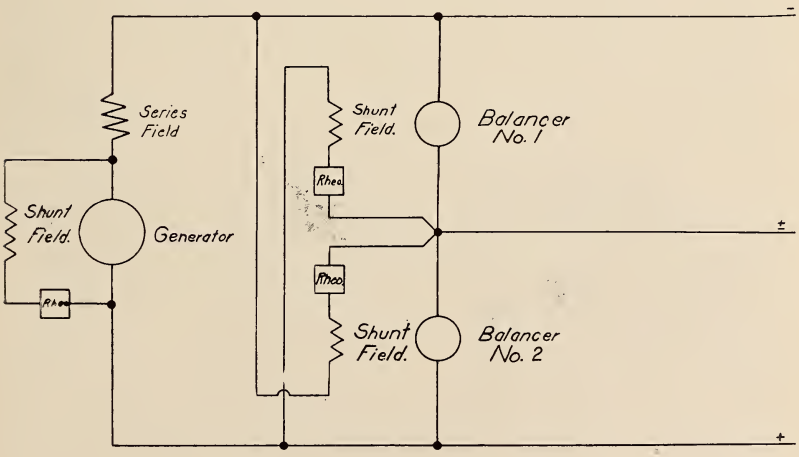
2 WIRE D.C. GENERATOR.
2 WIRE SYSTEM.

to the rapidly varying conditions which must be met by the studio electrician. In view of the foregoing statements, the ordinary commercial type of three-wire generator is not suitable for studio application where the unbalanced condition will often run as high as 30 to 40 per cent. While some may argue that such a condition is unwarranted and could be prevented by proper care in plugging in the lamps to maintain a better balanced condition of load, we must remember that time is a most valuable asset in film productions.

Two-Wire Generators with Balancer Set. In larger installations, using a three-wire system, it is practical to employ a two-wire generator of double the required voltage and produce the neutral or third wire by means of a balancer set. This balancer set consists of two compound-wound generators direct connected on the same shaft and mounted on a common base, mechanically.



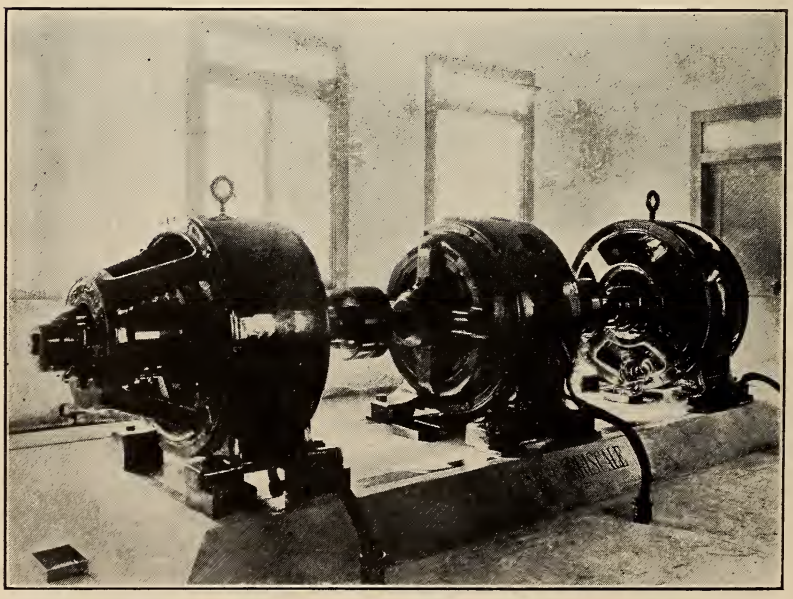
3 Wire Gen. 3 Wire System



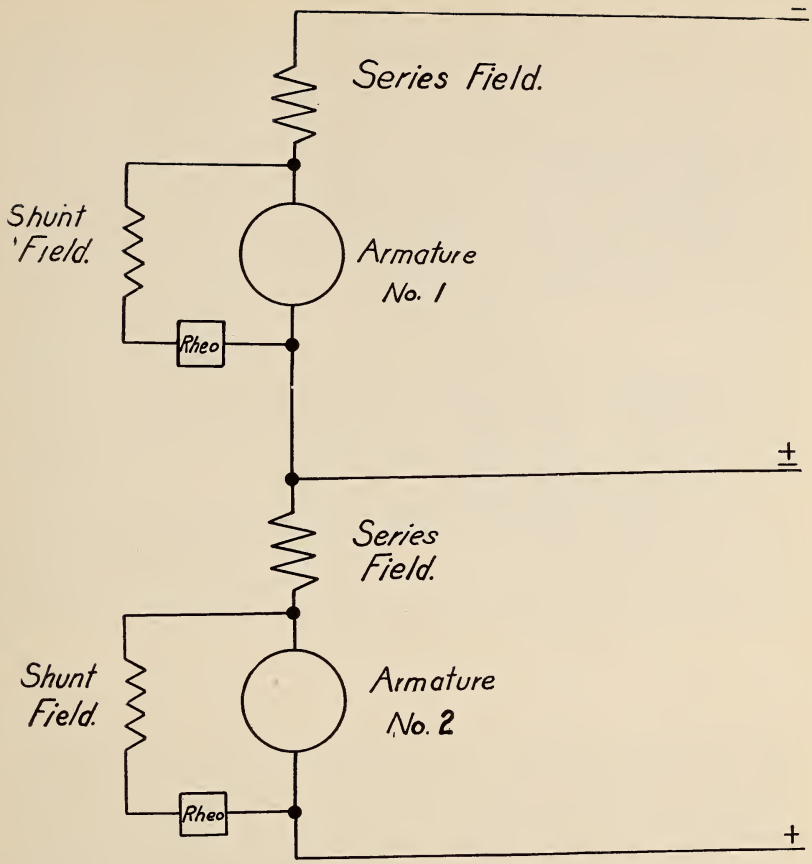
2 WIRE GENERATOR WITH BALANCE SET.
3 WIRE SYSTEM.

Electrically, they are interconnected across the leads of the two-wire machine and the electrical connection between the two units of the balancer set form the neutral or third wire. When one side of the system becomes loaded more than the other side, the fields of these two machines are interconnected in such a manner that the generator on the side with the lightest load becomes a motor and drives the other generator as a booster. In the event that both sides of the system are balanced both units of the balancer "float" on the line. The unbalance is limited to the capacity of the balancer unit used.

Two Two-Wire Machines Connected Permanently in Series. The three-unit motor-generator set, as the name implies, consists of one motor direct-connected to two generators, one on either side, all being mounted on a common base. The generators are permanently connected in series. The neutral is brought out from the connection between the two generators. It can readily be seen that with such combination, each generator can be loaded to its capacity, independent of the other, thereby giving the set a maximum unbalance up to 50 per cent. of its capacity. There are two other excellent advantages of this type over a straight three-wire generator. First, for any direct-current generator, for the basis of electrical comparison, it is a fundamental of design that the product of the KW. and the revolutions per minute is a constant. It is therefore evident that if instead of one large single generator,



120 K.W.-three unit set in Brunton Studios, Los Angeles, Cal.

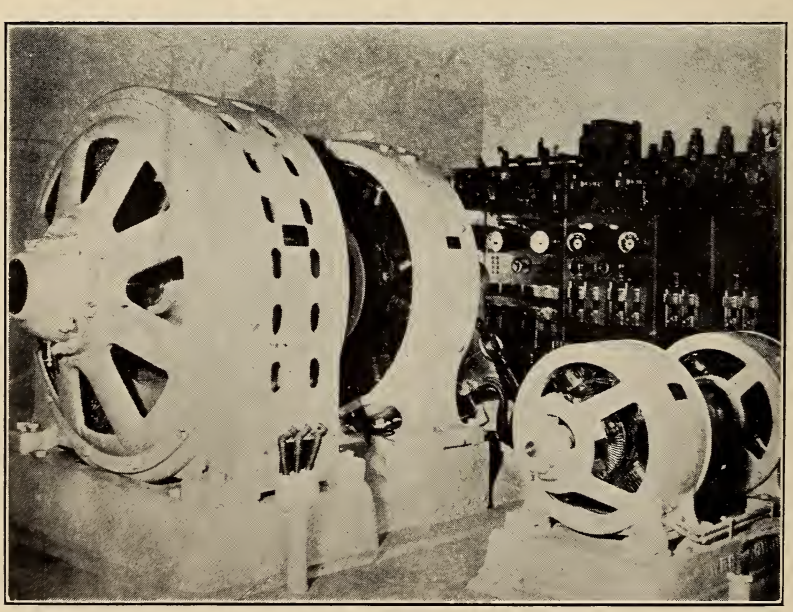


2 - TWO WIRE GENERATORS IN SERIES. 3 WIRE SYSTEM.

we could use two generators each of half the capacity that we could double our speed and still obtain about the same results as far as electrical performance and maintenance are concerned. The cost of the higher speed set is less than the cost of the lower speed set of the same capacity. Second, paralleling two two-wire machines operating as a three-wire system is less complicated than paralleling three-wire rotaries or three-wire generators.

Realizing that the question of unbalanced load also affects the voltage regulation and that it is absolutely essential to the studios to secure good voltage regulation regardless of what their unbalance would be, after consulting with electricians of several of the larger

150 K.W.-three unit set, Clunes Studios, Los Angeles



300 K.W.-two unit motor generator set with balancer, Metro Studio, Los Angeles

studios in the West, the use of a three-unit set was recommended as a solution of this problem. That this recommendation has worked out to good advantage, is without question. The first three-unit set tried out was installed at the Robert Brunton Studios in Los Angeles, California, and this set has now been in operation for more than two years and has given perfect satisfaction. Since then, additions have been made until their capacity is now 460 K.W., all in three-unit sets, on which they have standardized.

IV. CONCLUSIONS

Therefore, after a careful consideration of the many features that have been brought out, the conclusion is reached that the two types of apparatus best suited for converting alternating-current supply for direct current for studio illumination, are the rotary converter and the three-unit motor-generator sets for three-wire systems. The two-unit two-wire motor-generator sets might be best suited for small installations but it would certainly be third choice on larger installations.

Furthermore, we would especially call your attention to the fact that while the selection of proper equipment for supplying direct-current to the studio is of great importance, it is by no means the only problem which will have to be solved. The selection of proper switchboard for controlling and paralleling the generators and providing for the proper selection and protection of stage feeder circuits must be given careful consideration. Power transformers, where used must be of ample capacity and of the most suitable voltages. Proper protective devices must be installed to insure continuity of service and protection to human life.

Care should be used in placing apparatus in the power-house of the studio so as to keep to a minimum, the amount of floor space required and yet make all parts easily accessible for times of unforeseen emergency.

In laying out a new studio it would be well to make provisions for future extension. Failure to do this has already proven somewhat expensive to some of our large studios.

There are many other factors which should wisely be considered in making a complete electrical layout for the studio but we have discussed with you what we consider to be the most important and which must be settled before other details can be decided upon.

THE CONTINUOUS REDUCTION PRINTER

By Alexander F. Victor

Following the introduction and adoption of the Safety Standard film, the next logical step of progression was the creation of a supply of this film, adequate to the needs of the field it is to safeguard.

The most immediate and richest source of film subjects would naturally be the thousands of standard negatives already in existence.

Only one bit of apparatus was required to bring this treasure-trove into the immediate service of the home, school and church. A satisfactory reduction printer was the essential thing.

The existing reduction printers, while producing results of excellent quality, lacked the speed for quantity production, which is certain to be required in the enlarged field of Safety Standard Film.

Most of you are familiar with the step reduction printer, whereby the negative and positive film are moved step by step—the movements of the two being perfectly synchronized. The two films are some distance apart—a lens interpolated, and a light source back of the negative. A shutter masks the light exposure during the movement of the film. Owing to the reversing action of the lens, the two film strips must move in opposite direction. With the most accurate workmanship, it is impossible to operate two intermittent movements at a high rate of speed, without causing a certain amount of vibration. Obviously the step reduction process must be less speedy than a continuous method of printing.

So my ambition reached out toward the creation of a Continuous Reduction Printer. To realize this desire, all that appeared necessary would be to move the two film strips in opposite directions at an absolutely constant but dissimilar speed. Thereby the intermittent movement and the shutter would be eliminated.

Complicating my work was the fact that the two film strips are located at least ten inches apart, and would involve not less than three flawless gears. Gears so perfect that a combined error of a thousandth of an inch would render the scheme worthless.

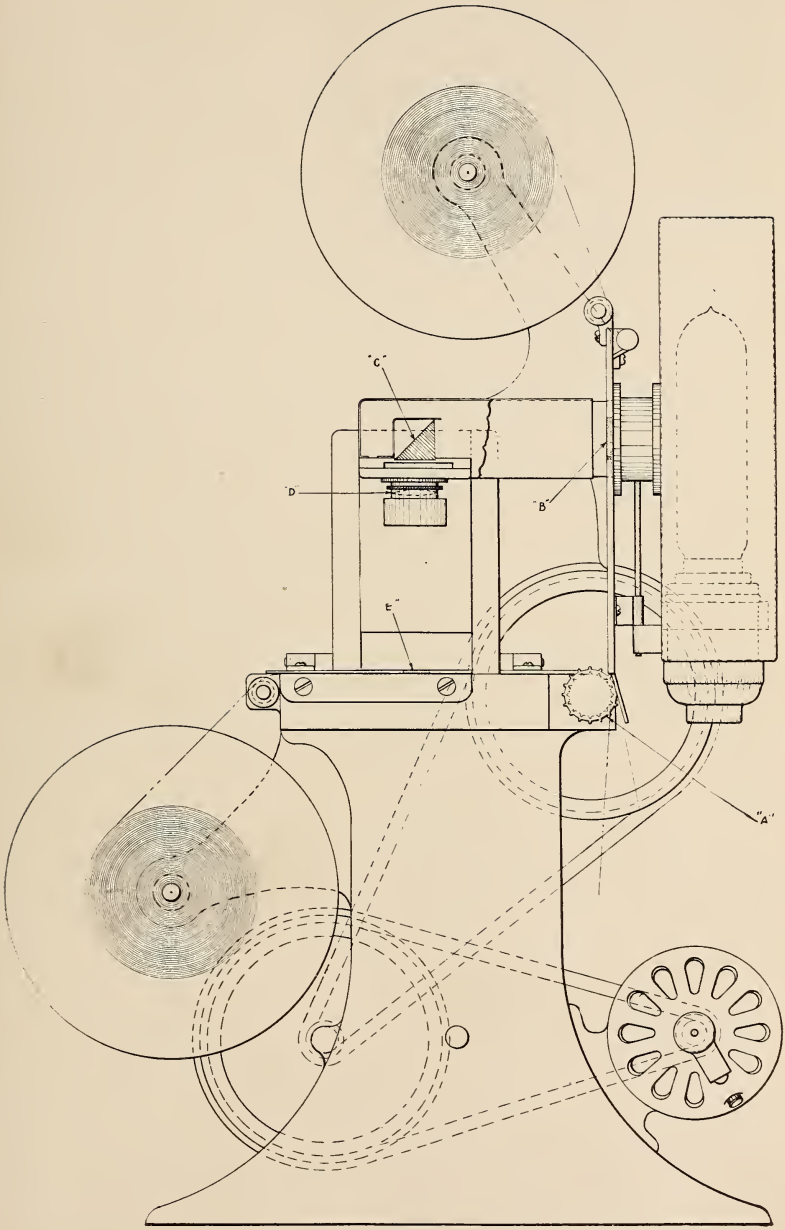
After several futile experiments, I reached this simple solution of my problem. Since the action of the lens, in reversing the image, necessitated the movement of the film strips in opposite directions, it must logically follow that a second reversal of the image on the positive would permit the travel of the two trips in the same direction.

To accomplish the second reversal of the image I used an internal reflecting prism. In addition to a second reversing of the image, this prism performs another essential service.

I will explain.

If you will refer to illustration you will note that the special sprocket (A) is provided with two sets of teeth.

The positive film travels over the small drum, between the teeth



CONTINUOUS REDUCTION PRINTER (VICTOR)

of the larger, which engage the negative strips. The teeth are cut on the same arbor, used for turning the sprocket itself.

Possibility of error is therefore reduced to the negligible quantity of imperfect arbors, machines or milling cutters.

Since the two strips are fed simultaneously and on the same shaft, they must necessarily advance at the exact speed ratio assigned to each.

However, I was confronted with the fact that this arrangement did not allow for the interpolation of a lens, if the two film strips were arranged parallel to each other.

The internal reflecting prism by deflecting the image 90 degrees permits this separation of the two film strips.

Again referring to the illustration. The aperture "B" permits illumination to penetrate the negative, forming an image on the positive at point "E," after passing through prism "C" and lens "D."

The result is exactly that which would be obtained if the two strips were placed in actual contact, with the desired reduction feature added.

The aperture "B" may be narrowed or widened to obtain the proper exposure.

An alternative method of governing the exposure may be gained by controlling the brilliancy of the light source.

The prism "C" is slightly rotatable, allowing for the correction of faulty camera frame lines. This feature is a distinct innovation in continuous printers; even contact printers do not possess this advantage.

Another advantage possessed by the Continuous Reduction Printer is the fact that no feed sprockets are required. The single sprocket smoothly and evenly unreels the material from the reel direct.

A variation of the apparatus described, introduces a geneva type of intermittent movement which I use in printing titles. In making titles the positive film is fed forward step by step, while a stationary negative at aperture "B" carries a single negative element which is duplicated the necessary number of times. A shutter is made to mask the light during the movement.

Needless to state, a negative film strip may be used in conjunction with this method and moved step by step with the positive. The apparatus thus becomes a new form of Step Printer.

Another variation of the Continuous Reduction Printer eliminates the reduction feature, applying the advantages of this type of printer to regular standard film.

In all its variations this apparatus is equipped with a suitable motor, with easily regulated speed control; although if desirable the machine may be operated by hand.

I believe the Continuous Reduction Printer is possessed of many new and desirable qualities, which the engineers of the industry will welcome; and it is a pleasure and an honor to first present it to the Society of Motion Picture Engineers.

STEREOSCOPIC MOTION PICTURES

C. Francis Jenkins

Stereoscopic motion pictures, that is, motion pictures projected in such manner that the optence sees them in true simulation of all the wonderful depth, perspective and solidity of the real scene itself, has been the problem of photographers since Daguerre made his first twin "tintypes." Its practical solution has engaged the attention of the most brilliant minds, but remains unattained. By practical method I mean commercially useful, or profitable perhaps I should say. And this probably means stereoscopic vision without eye aids. It seems to be a much more difficult task than motion pictures in natural color.

Now that motion pictures have attained world-wide acceptance, the large financial return possible on the introduction of any new thing the public approves, warrants a correspondingly large appropriation for investigation and experimentation. For this reason it is believed that this problem will be taken up by motion-picture engineers sooner or later with sufficient financial backing to insure that persistent investigation which most nearly guarantees success.

It is likely, therefore, that a report of experiments made by the writer, covering a period of years, some of them original and some of them an effort to carry the work of others nearer the goal, may be worth recording.

Doubtless it will be conceded that stereoscopic picture projection will never be publicly acceptable, and therefore, profitable, until they are attained without requiring each individual of the audience to hold some sort of a device before his eyes. Better yet, the pictures should appear stereoscopically whether viewed with one or with two eyes.

Several different methods have been employed in attacking the problem. All those I shall describe in detail produce stereoscope motion pictures on the screen; and the results of some of the methods are really beautiful, and in some scenes, as, for example, looking at a forest across a wooded ravine, a true impression is obtained, which cannot be secured in any other way, and is very striking.

Perhaps one of the simplest methods, though not the best as to results, consists in projecting the separate picture frames of a film alternately through red and through green tinters, alternate frames having been made through right eye and left eye camera lenses, that is, left eye frames occur between right eye frames throughout the length of the film. The red and the green of both the filters and tinters must be complimentary and the composite screen picture must be viewed through corresponding red and green filters. These color filters may conveniently be glass or gelatine, and supported in spectacle frames, for example, although in 1898 a circular paper fan was used with two openings therein through which the eyes looked at the screen picture, these being covered

with colored gelatine. The cost of these fans was met by selling the advertising space thereon to a local merchant. These color filters before the eyes select the view for each eye, that is, they permit the right eye seeing only the right eye picture and the left eye seeing only the left eye picture, and a stereoscopic picture is the result. The picture is seen in stereoscopic relief, but only in monochrome, not in colors, as one might at first suppose. Both the filters and tinters may be any two tints; the right shades of red and green, red and blue, blue and yellow, or any others that are complimentary; that is, any two which laid over each other are no longer transparent.

Another method, somewhat similar, is to project with polarized light, all right eye film frames being projected with light polarized in a vertical plane, and all left eye frames with light polarized in a horizontal plane. The screen picture is then viewed through spectacles holding analyzers before the eyes, the right eye being in crossed relation to the left eye analyzer. This method has the same two objections as the first mentioned method, namely, (1) a 75 per cent. loss of light, and (2) requiring a viewing device.

A third method secures a 100 per cent. efficiency of light on the screen, but still has the objection of a viewing device. This consists of an opera glass through which the screen picture is viewed and having therein a reciprocating shutter, electrically actuated, to cut off the view of first one eye and then the other in synchronism with the alternate projection of the right eye and the left eye picture frames. This synchronism is obtained by electrically connecting the opera glass of each observer with a commutator on the sprocket shaft of the projecting machine. The pictures obtained are really very fine, especially if selected to bring out most effectively the striking value of plasticity and perspective.

Another method, somewhat similar, consists in projecting the pictures side by side on a double width screen, either alternately or simultaneously and viewing them through a pair of opera glasses (or plain tubes) having fitted in front of them suitable prisms for turning the eyes outwardly so that the left eye sees only the left picture and the right eye only the right screen picture. The projecting machine will be fitted with a device for alternately interposing in the path of light, perhaps before the projection lens, two prisms of, say, 10 degrees, with bases opposite, so that the right frame is projected onto the right screen, and the left frame the left screen. This presupposes the use of but a single standard film (as in the methods described earlier herein), the film carrying alternate stereoscopically-taken frames in single-line sequence; and fitting to the projector a prism-carrying device. Of course, two films or two rows of frames on a double width film can be used.

A somewhat newer method consists in projecting the stereoscopically made pictures through a vertical grating hanging a few inches in front of the screen. This grating was made of threads having, as near as could be obtained, a uniform diameter, from top

to bottom, and so spaced that the distance between adjacent threads was the same as the diameter of the thread. The right eye picture frames are all on one film and the left eye frames all on another film, the right eye film projected from a machine placed some distance to the right of an imaginary line drawn from the centre of and perpendicular to the surface of the screen, and the left eye film from a machine located on the left side of this line. The two machines superimpose their pictures and run synchronously. The grating has the effect of splitting up the projected picture from, say, the right machine into thin vertical slices or segments with a shadow (of the thread) lying between each adjacent picture segment. The left eye picture projected by the other machine is also cut up into vertical slices, each of which falls on the screen in the shadow of the string in the light of the right projector. The result is a composite picture consisting of alternate right eye and left eye vertical picture-segments, the segments entirely imperceptible to the observer. One may, therefore, view this screen picture from such an angular location that the right eye sees only the right eye vertical segment and the left eye only the left eye vertical segments, the picture as a whole in stereoscopic relief, and without any artificial aid, i. e., any device over the eyes. It is obvious that one may view the picture stereoscopically only from certain zones, the angle of the eyes from these zones being approximately the angle of projection of the two machines. So, again, we fall short of practical attainment.

But certain kinds of pictures can be obtained which appear stereoscopic to the unaided eyes, in fact appear so viewed with but a single eye. These are obtained by carrying the camera on a train, boat, automobile, or hand truck, the lens pointing at more or less of an angle to the line of travel of the camera-supporting vehicle. There is no doubt but that where appropriate this method puts interest in a picture which might otherwise be dull. In spite of the fact that pictures of this kind have been made for many years past, patents—both foreign and domestic—were issued thereon recently, which would seem to indicate that patent examiners don't go to the "movies."

A method devised some five years ago consisted in moving the background, and depth is fairly simulated, but roundness of nearby objects is purely mental delusion. We are prone to imagine solidity, shape, and other characteristics because, when we recognize the object, we recollect its form and unconsciously clothe it with its true mass contour. This is not true stereoscopy, and is valueless when applied to strange objects or scenes.

In the last two schemes mentioned just a plain ordinary motion-picture camera is sufficient, though it may be useful to some of you when you take up the problem to learn how the camera was constructed to secure right and left pictures of the same object in single line sequence on a single standard negative film. The most satisfactory form employed consisted of a standard type camera having

two right-angle prisms, one mounted (on the front of the box) on each side of the lens and so placed as to reflect across the camera front any view of object in front of the camera. Just in front of the lens and in axial line therewith, two smaller prisms were mounted, to reciprocate vertically, the travel being the thickness of one of the prisms. The prisms were crossed, and the reciprocating crank (run at half shutter speed) so timed that the prisms were alternately brought into position before the lens in time with the opening and closing of the shutter. Obviously such an arrangement reflects into the lens a view from first the right prism and then the left prism, so that the negative, when developed, carries alternately right and left eye frames.

The exact distance of the centres of the outside (stationary) prisms is a matter of no particular moment, though 3 inches is convenient and perhaps the best distance. To place them close together exaggerates the size of objects; placing them farther apart makes objects appear smaller, for the base line of the angle photographed is, in the mind when we look at the resultant picture, assumed to be the base line of the angle of vision, that is, the width between the pupils of the eyes.

Doubtless from this thought your mind has run ahead of me questioning, in anticipation, the effect of pictures made from base lines of 25, 50 and 100 feet when viewed in a stereoscope, and what practical application can possibly be made of it.

This question I will answer for you if I find sufficiently valuable pictures I am making from cameras located at the wing tips of a flying machine, and simultaneously exposed. It seems probable that these will be useful in conjunction with map-making cameras because it will give a relative idea of the heights, of known and unknown objects, and if further work proves the scheme has merit I shall be glad to lay the matter before you in detail, perhaps at our next meeting.

TRANSACTIONS

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

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Number Ten

MEETING OF MAY 9, 10, 11, 1920

MONTREAL

TRANSACTIONS

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

Number Ten

MEETING OF MAY 9, 10, 11, 1920
MONTREAL

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Membership in the Society of Motion Picture Engineers stands for unselfish service to the Industry. Applications for membership are by invitation and endorsement. All checks should be made payable to the Society of Motion Picture Engineers.

All receipts are expended directly to promote the objects of the Society and the interests of its members. There are no salaries or emoluments of any kind.

The following are extracts from the By-Laws:

The objects of the Society are: The advancement in the theory and practice of motion-picture engineering and the allied arts and sciences, the standardization of the mechanisms and practices employed therein and the maintenance of a high professional standing among its members.

An Active Member is one who is actually engaged in designing, developing or manufacturing materials, mechanisms or processes used in this or allied arts, or who is interested directly in the art.

Any person of good character may be a member in any or all classes to which he is eligible.

Prospective members shall be proposed in writing by at least one member in good standing, and may be elected only by the unanimous vote of the Board of Governors.

All applications for membership or transfers in class shall be made on blank forms provided for the purpose, and shall be accompanied by the required fee.

The entrance fee for all members shall be thirty-five dollars ($35.00). The annual dues shall be fifteen dollars ($15.00), payable in advance before the annual meeting (October) of each year. That is, the total fee for the first year which includes the entrance fees and first annual dues, is $50.00 for all members.

Motion Picture Standards Adopted in Committee of the Whole Society

The following have been adopted as standards by the Society of Motion-Picture Engineers, and are promulgated to encourage uniformity and standard practice throughout the Industry as a whole. Their early universal adoption will save the industry a great deal of present annoyance and monetary loss.

Film Speed—A film movement of sixty feet per minute through motion-picture mechanisms shall be considered as standard speed.

Film Perforation—The dimensions and location of film perforation shall be in accord with the illustrating diagram herewith.

Frame Line—The dividing line between pictures on motion-picture film shall lie exactly midway between the marginal perforations.

Intermittent Gear Ratio—The movement of the intermittent gear shall be expressed in degrees of rotation during which the pin of the driver is in contact with the slot of the driven gear. For example, a gear in which the pin is engaged with the slot for one-quarter of a revolution of the driver shall be called a 90-degree movement; that in which the pin is engaged with the slot for one-sixth of a revolution shall be called a 60-degree movement, etc.

Lantern Slide Mat Opening—A standard opening in mats of lantern slides for use in conjunction with motion pictures shall be 3 inches wide by 2¼ inches high.

Thumb Mark—The thumb mark spot on a lantern slide shall be located in the lower left hand corner next the reader when the slide is held so as to be read against a light.

Lantern Strip—A red binding strip to be used on the lower edge of the lantern slide.

Picture Aperture—The standard film picture aperture in a projecting machine shall be 0.906 inch wide and 0.6795 inch high, namely, 29/32″ and 87/128″.

Projection Angle—The maximum permissible angle in picture projection shall not exceed twelve degrees (12°) from a perpendicular to the screen surface.

Projection Lens Foci—The focus of motion-picture projection lenses shall increase in ¼″ steps to 8 inches and from 8 to 9 in ½-inch steps.

Projection Lens Mounting—Picture projecting lenses shall be so mounted that the light from the film picture aperture shall have an uninterrupted full path to the rear component of the lens.

Projecting Lens Height—The standard height from the door to the center of the projecting lens of a motion picture machine shall be 48 inches.

Projection Lens Opening—The diameter of unit opening for projecting lens holder shall be 1 15/16 inch.

Projection Objectives—Shall have the equivalent focal length marked thereon in inches and quarters and halves of an inch, in decimals, with a plus (+) or minus (—) tolerance not to exceed 1 per cent of the designated equivalent focal length also marked by the proper sign following the figure.

Reel—The approved standard reel shall be 10 inches in diameter; 1½ inches inside width; with 5/16-inch center hole, with a key-way ⅛″ by ⅛″ extending all the way through; a 2-inch hub; and a permissible flange wabble of not more than 1/16-inch.

Standard Picture Film—Shall be one and one-third inches wide, and carry a picture for each four perforations, the vertical position of the picture being longitudinal of the film.

Standard Reel Film—Shall have black film leaders, with tinted (red, green or blue) trailers; should have marking thereon embossed rather than punched in the film; and each reel of a multiple-reel story should end with a title, and the next reel begin with the same title.

Take-up Pull—The take-up pull on film shall not exceed 15 ounces at the periphery of a 10-inch reel or 16 ounces on a (11-inch) reel.

Standard Non-Inflammable Film—Standard adopted for approved non-inflammable film is illustrated in the diagram below:

Motion-Picture Nomenclature

SOCIETY OF MOTION-PICTURE ENGINEERS

Adopted as Amended in Committee of the Whole, as Recommended in the Report of Nomenclature Committee.

Rules which Governed the Committee in its Recommendations

It was believed that—

(1) The Committee should give to words used in older arts and industries, their previous accepted meaning.

(2) Definitions of words should be selected which define their meaning rather than explain uses.

(3) Definitions should be as short as consistent with unquestionable identification.

(4) Definitions should not be included in the list which are so self-evident or of such wide use as to make our work seem cumbersome and trifling.

And that the following three classes of words only be defined:

(1) Expressions belonging to the projection industry alone, the meaning of which has long been accepted by the whole industry.

(2) Expressions from other industries used universally in motion-picture work, with specialized meanings.

(3) Expressions the meaning of which may be difficult to find in ordinary reference books or which are already used in more than one way in other industries.

ACTION—The director's command to the players to begin performing.

BACK FOCUS—Properly called working distance.

BUSINESS—Action by the player; e. g., business of shutting door.

BUST—A small, magnified part of a large scene.

CAMERA—An expression used to command the photographer to begin taking the scene.

CHANGE OVER—The stopping of one projecting machine and the simultaneous starting of a second machine in order to maintain an uninterrupted picture on the screen when showing a multiple-reel story.

CINE—A prefix used in description of the motion-picture art or apparatus.

CLOSE-UP—Scene or action taken with the character close to the camera.

CONDENSERS—The lens combination which deflects the diverging rays of the luminant into the objective.

Collector Lens—The lens next to the source of light.

Converging Lens—The lens nearest the objective.

Middle Lens—Of a three-lens combination, the lens lying between the collector lens and the converging lens.

Cutting—Editing a picture by elimination of useless or unacceptable film.

Cut-Back—Scenes which are returns to previous action.

Cut-In—Anything inserted in a scene which breaks its continuity.

Developing—Making visible the latent image in an exposed film.

Dissolve—The gradual transition of one scene into another.

Director—The person who directs the actual production of the photoplay.

Double Exposure—The exposure of a negative film in a camera twice before development.

Double Printing—The exposure of a sensitive film under two negatives prior to development.

Douser—The manually operated door in the projecting machine which intercepts the light before it reaches the film.

Dupe—A negative made from a positive.

Effective Aperture—The largest diameter of a lens available under the conditions considered.

Equivalent Focus—The equivalent focus of a plurality of lenses in combination is the focal length of a simple thin lens which will under all conditions form an image having the same magnification as will the given lens combination.

Exterior—A scene supposed to be taken out of doors.

Fade-In—The gradual appearance of the picture from darkness to full screen brilliancy.

Fade-Out—The gradual disappearance of the screen-picture into blackness. (The reverse of fade-in).

Feature—A pictured story, a plurality of reels in length.

Fixing—Making permanent the developed image in a film.

Flat—A bit of painted canvas, or the like.

Flash—A short scene, usually not more than three to five feet of film.

Flash-Back—A very short cut-back.

Footage—Film length measured in feet.

Frame (verb)—To bring a frame into register with the aperture during the period of rest.

Frame (noun)—A single picture of the series on a motion-picture film.

Frame Line—The dividing line between two frames.

Intermittent Sprocket—The sprocket which engages the film to give it intermittent movement at the picture aperture.

Iris—An adjustable lens diaphragm.

Irising—Gradually narrowing the field of vision by a mechanical device on the camera.

Insert—Any photographic matter, without action, in the film.

Interior—Any scene supposed to be taken inside a building.

Joining—Splicing into a continuous strip (usually 1,000 feet) the separate scenes, titles, etc., of a picture.

Lantern Picture—A still picture projected on a screen by means of an optical lantern or stereopticon.

Lantern Slide (see slide)—The transparent picture from which a lantern picture is projected.

Leaders—That piece of blank film attached to the beginning of the picture series.

Light Beam—A bundle of light rays.

Light Ray—A thin line of light.

Location—Any place selected for the action of an outdoor scene.

Magazine Valve—The film opening in the magazine of a motion-picture projector.

Masks—Opaque plates of various sizes and shapes used in the camera to protect parts of the negative from exposure.

Motion-Picture—The synthesis of a series of related picture elements, usually of an object in motion.

Motion-Picture Film—The ribbon upon which the series of related picture elements is recorded.

Motion-Picture Projector—An optical lantern equipped with mechanisms for suitably moving motion-picture film across the projected light.

Movies—Motion pictures.

Multiple-Reel—A photoplay of more than a thousand feet of film in length.

Negative—The developed film, after being exposed in a camera.

Negative Stock—Light sensitive film intended for motion-picture camera use.

Objective—The picture-forming member (lens) of the optical system.

Optience—A collection of persons assembled to see motion pictures.

Pam—Contraction for panorama.

Panoram—The act of, or device for, turning a motion-picture camera horizontally, to photograph a moving object, or to embrace a wide angle of view.

Photoplay—A story in motion pictures.

Positive—The developed film, after being printed through a negative.

Positive Stock—The light-sensitive film intended to be printed upon through a negative.

Pre-Release—A picture not yet released for public showing.

Print—Same as "positive."

Producer—The maker of photoplays.

Program—The complete show for a single optience.

Props—Contraction of properties. Objects used as accessories in a play.

Projection Distance—The distance between the objective and the screen of a stereopticon lantern or motion-picture projecting machine.

Projecting Lens—Properly called projection objective.

Projection Objective—The objective which forms an image of the lantern slide or film, upon the screen.

Reel—The flanged spool upon which film is wound for use in projecting machines.

Reel—An arbitrary unit of linear measure for film—approximately a thousand feet.

Register—A term denoting facial expression of emotions.

Release—The publication of a photoplay.

Retake—Rephotographing a scene.

Rewind—The process of reversing the winding of a film, usually so that the end to be first projected shall lie on the outside of the roll.

Rewinder—The mechanism by which rewinding is accomplished.

Scene—The action taken at a single camera setting.

Scenario—A general description of the action of a proposed photoplay.

Screen—The surface upon which a picture is optically projected.

Shooting a Scene—Photographing the scene.

Shutter—The obscuring device, usually a revolving segmental disc, employed to intercept the light during the movement of the film in motion-picture apparatus.

Shutter—Working blade—(also variously known as the cutting blade, obscuring blade, main blade, master blade or travel blade). That segment which intercepts the light during the movement of the film at the picture aperture.

Shutter—Intercepting blade—(also known as the flicker blade). That segment which intercepts the light one or more times during the rest or projection period of the film to eliminate flicker.

Single Picture Crank (sometimes referred to as trick spindle)—That spindle and crank on a motion-picture camera which makes one exposure at each complete revolution.

Slide (Stereo slide)—The transparent picture from which a screen still is projected.

Splicing—Joining the ends of film by cementing.

Split Reel—A reel having two or more picture subjects thereon.

Spot—The illuminated area on the aperture plate of a motion-picture projector.

Sprocket—The revolvable toothed member which engages the perforations in the film.

Stereopticon—A lantern for projecting transparent pictures, i. e., lantern slides, often a double lantern for dissolving.

Still—A picture from a single negative.

Take-Up (noun)—The mechanism which receives and winds the film after it passes the picture aperture.

Take-Up (verb)—Winding up the film after it passes the picture aperture.

Throw—Projection distance.

Tilt—The act of, or device for, moving a camera vertically while in use.

Tinting—Coloring a film by dyeing the gelatine side of it.

Toning—Coloring a film by chemical action on the silver image.

Trick Crank—A camera crank giving a single exposure for each turn.

Trick-Picture—A picture in which unnatural action appears.

Trailer—That piece of blank film attached to the end of a picture series.

Vision—A new subject introduced into the main picture, by the gradual fading-in and fading-out of the new subject, as, for example, to visualize a thought.

Working Distance—The distance from the principal focus of a lens to its nearest face; e. g., the distance from the slide or film to the nearest lens of the objective.

Remote Control Switchboards for Motion-Picture Studios

By H. A. MacNary

In papers presented to the Society of Motion-Picture Engineers on the various phases of studio lighting, the great need for flexibility in the lighting facilities has been well covered. For this reason, it is felt to be unnecessary to go into the arguments for flexible operation. The able papers presented by Messrs. Mayer and Allison will be found to cover this subject in a comprehensive manner.

Nearly all of the studios at the present time are equipped with the wall pocket method. A brief outline of this is as follows at given distances usually every 20 to 30 feet around the wall of the studio stage there are wall pockets of usually 100-amp. size either 2 or 3 wire, depending upon the character of the supply. These wall pockets are controlled from a stage switchboard which is usually made up as follows. There is a double set of bus on the back of the board one that is always alive and the other dead or alive, depending upon the position of the master switch. Each and every wall pocket is connected to the middle point of a double-throw knife switch either 2 or 3 pole, the one side is connected to the live bus, the other side connected to bus controlled by the master switch. This gives a flexible outfit because any light effect can be made by placing all lights to come off at one time on the master switch. It is common practice to have not more than six switches to each master. Take a large studio where there may be 6 to 8 companies working and imagine the confusion when a number of electricians are signalling for light effects all at the same time. Also the mass of cable strewn on the floor because all the cables must come from these wall pockets.

Fig. 1. A Typical Studio Scene When Remote Control is Not Used.

The above is a typical example of cable strewn on studio floor. This not only hinders stage workers in moving props, but also shortens the life of cable by being cut and destroyed by people walking and dragging lamps and apparatus over it. These are a few of the reasons for remote control.

By remote control switchboards for moving-picture studios we mean a board made up of contactors instead of switches, a switchboard that can be operated from a point far distant from the switchboard itself, thus eliminating the necessity of signalling by electricians or by telephone or enunciators. The remote control is an overhead scheme and this also gets rid of cable all over the floor. This will be seen later as the remote control system is described.

In a small studio, where there are only one or two companies to work, one to two remote control boxes would be used; probably one box to each company. They would be mounted overhead, either on the wall or on runway. The following diagram represents a typical installation. Boxes will be lettered A, B, etc., and so on depending upon the number in each of the boxes which will be described in detail later as 4 or 6 Kliegl receptacle and plugs 100 amp. capacity, either two or three wire. For this example we will use two boxes, A and B, using 6 Kliegl 3 wire receptacles and plugs. The remote control contactor boxes would be mounted overhead on runways; these would each have its separate feed coming from a small feeder board having a 600-amp. fused switch for each box.

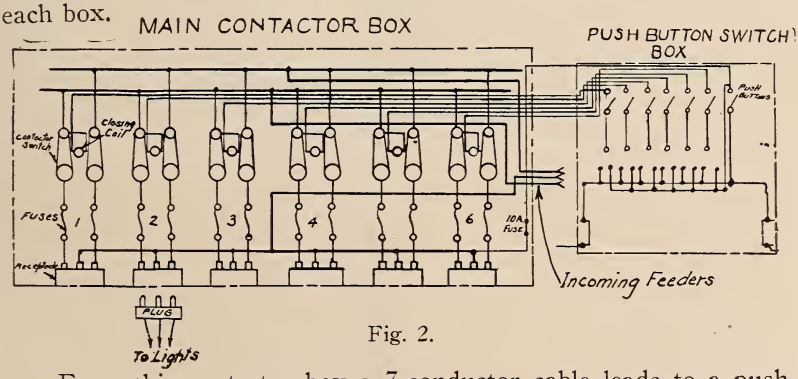


Fig. 2.

From this contactor box a 7-conductor cable leads to a push-button station. This push-button station is portable and may be carried to any part of the studio floor.

Description of Contactor Box

We will take the whole system and describe each separate part, first the contactor box. The contactor box is made up in 4, 6 and 8 outlet sizes, with either removable back or top. It is made of 10-gauge sheet iron. We will describe in detail a six-outlet box. The box is 60 inches long, 30 inches wide and 20 inches deep; along the bottom equally spaced are 6 Kliegl 3-wire, 100-amp. receptacles into which cables from the stage spiders are plugged. At first these cables were entered directly into the receptacles but a recent

improvement in the box comprises an eye-bolt, which assumes the weight of the cables and removes all tension from the plugs and receptacles.

Directly above the tops of the receptacles and a little to the rear is suspended the neutral or middle leg of the three-wire system. The middle points of all receptacles are connected to this leg. One point of this bus bar is a connector to which the main incoming feed is connected. Directly above this middle or neutral leg is a slate panel 9 x 60 x 1¼. This panel is held in place by being bolted to a 2 x 2-inch angle which runs from top to bottom of the contactor box. On this slate are mounted twelve 100-amp., 250-volt enclosed fuses and fuse holders. The two outside points of the receptacles are connected to these fuses.

Above this panel is another slate panel, 12 x 60 x 1¼. On this panel are mounted the six two-pole 125-ampere contactors. Behind these contactors are suspended the other two legs of the three-wire

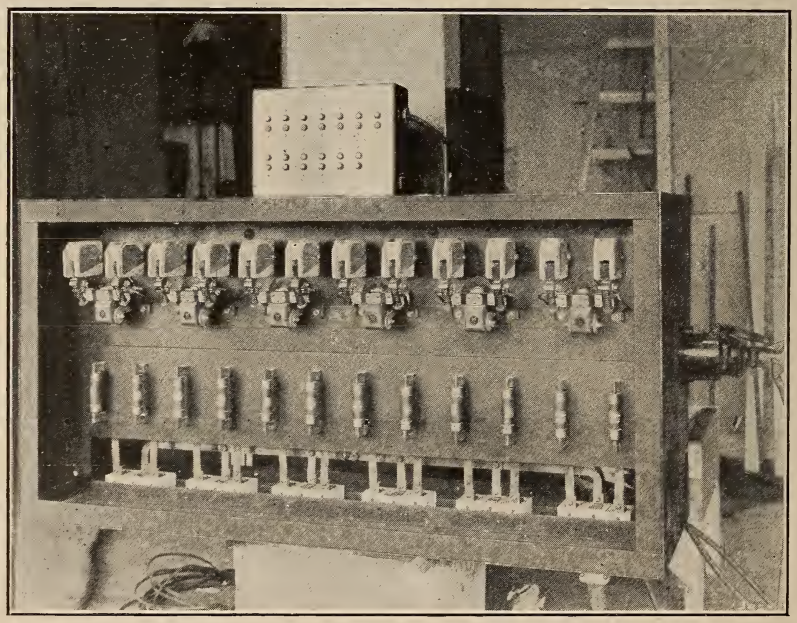


Fig. 3.

systems. One leg goes to one pole of the contactor and the other leg to the remaining pole. The circuit is completed by connecting the other side of the two-pole contactor to the top side of the fuses directly underneath. The contactors are light, being made of pressed steel. They are the back connected type fitted with blow-out coils which has proved to be a valuable feature for studio work because of the high inductive load usually encountered. The contactors are closed against the action of a spring by means of a

coil with an iron core acting as a magnet. One side of the coil is connected to the positive leg of the three-wire system and the other side is brought out to one side of the box to the female portion of a train line connector. This accounts for six of the leads. The seventh is brought from the neutral leg to the same train line connector.

Description of Push-Button Station

The male portion of the train line connector just referred to connects to the seven-conductor flexible cable leading to the push-button station located wherever necessary.

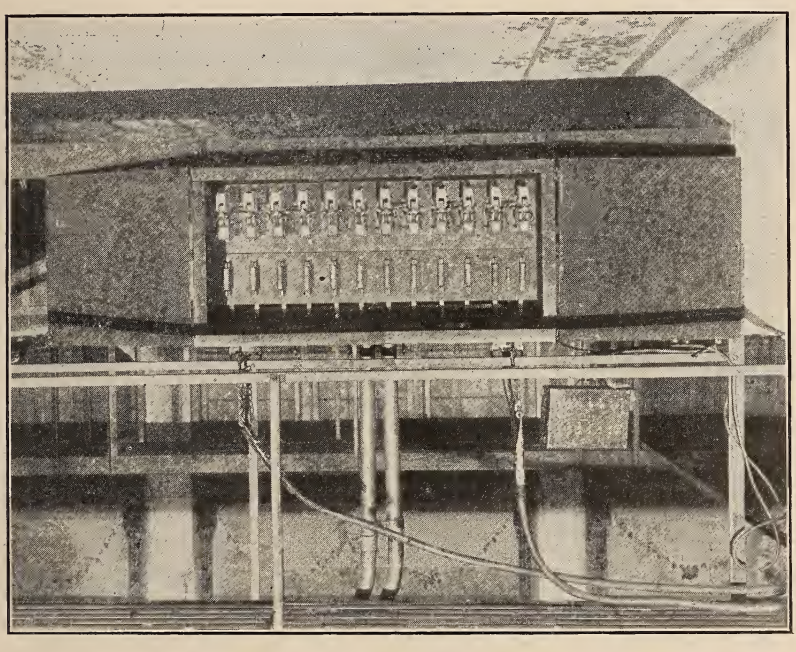


Fig. 4.

These push-button stations are small sheet-iron boxes, 16 x 10 x 6. The cover is a brass gang plate accommodating 13 push buttons, seven in the top row and 6 in the lower row. On one side of the box is a handle to simplify carrying.

The type of push-button station now in use is as follows: The top row of push buttons are of the ordinary house type, "on" and "off." These are numbered 1, 2, 3, etc., up to six. The seventh button is labeled "Master." The lower row of buttons are of the "three-way" type. One side of the "on" and "off" buttons is connected to binding-posts on the outside of the box numbered to correspond to the number of the button from which it comes The other side is connected to the middle point of the three-point buttons.

Of the two remaining points of the three-way buttons one terminal of each is connected to a common wire which in turn is connected to the "off" side of the "Master" button. The third and last point of each button is connected to a common wire which leads to the live side of the "on" and "off" "Master" button. The live side of the "Master" button is connected to the seventh binding-post on the outside of the box. The numbers on the binding-posts must be connected to the corresponding number on the contactor box.

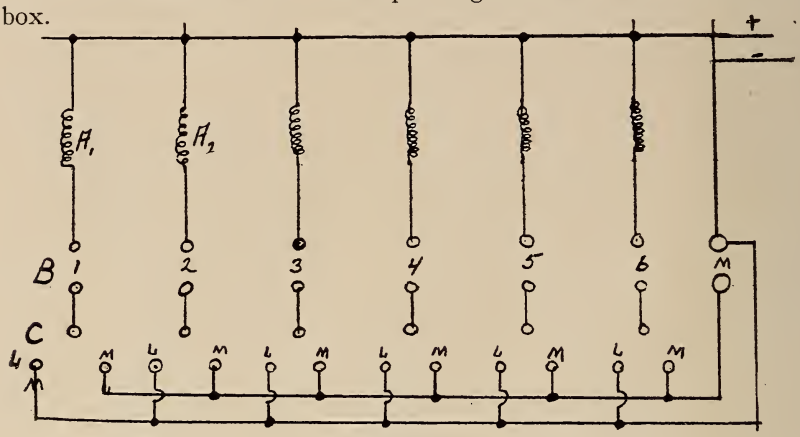


Fig. 5.

How the System Operates

In this diagram the line across the top is the positive side of the line, the coils lettered A_1, A_2, and so on to A_6, are the shunt coils of the contactor. The letters *B*, 1, 2, 3, and up to the one marked *M* are the ordinary on and off push-buttons and correspond to the top row of buttons on the push-button station; the three-point button labelled *C* is the bottom row of buttons on the push-button station and the side labelled *L* jumps the Master button and goes to the live side of the Master button; the live side of the Master button is connected to the negative or to the neutral wire, depending on whether the coil of the contactor is for 115 or 230 volts. The side of the button labelled *M* goes to the off side of the Master button and is therefore controlled by it.

Perhaps the easiest way to follow the working of the apparatus is to take a definite example such as the studio electrician is apt to run across. We will assume that he has a set that will require the use of all six contactors and also that he wants to cut off a number of lights at one time for an effect we will say the lights to come off will be placed on contactors 1, 3, and 6 and at a later time in the set he wants to take off all the lights connected to contactors 2 and 4. The first thing he does is to throw the main feed switch for the contactor box; next he puts in the stage plugs in the bottom of the contactor box, carries the cables with the

spider boxes along the runway and drops the spiders down to the studio stage alongside of the set just where they are needed and plugs in his lamps. He now takes his push-button station and plugs that in the contactor box and drops this down to the floor right next to the director and camera man. The electrician knows what lights are on each contactor and he has the effect as stated above. He now adjusts the push-button box, like the following diagram; that is, he closes the one and off buttons numbers 1, 3 and 6, and then that is all he has to do to the upper row until he is ready to shoot the picture. In the bottom row he throws the buttons of 1, 3 and 6 to the side marked "Master" and the buttons marked

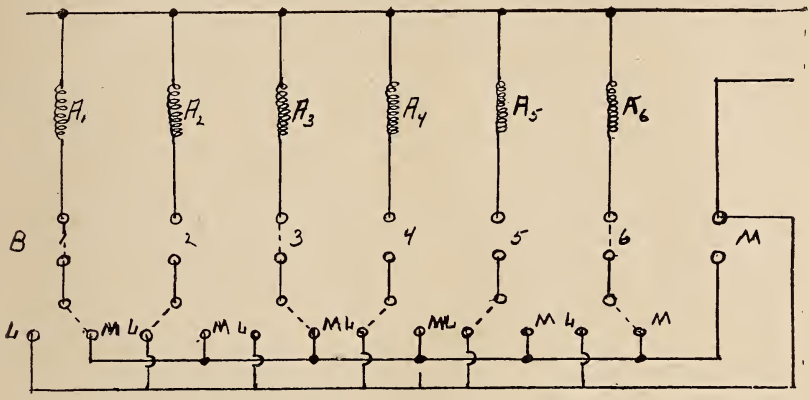


Fig. 6.

2, 4 and 5 are pushed into the side marked "line." The set is now ready for operation. Let us follow through all of the connections and we will find that there are no lights on.

The director now calls for lights. The electrician now closes the Master button and if you will follow through connections you will find that this closes contactors 1, 3 and 6, which gives lights that are connected to these contactors. He now pushes buttons marked 2, 4 and 5 to the "on" position and this gives all the lights on the set. He receives his cue to take off lights that are on the contactors 1, 3 and 6. He does this by simply pushing the Master button into the "off" position; the set continues and the electrician gets his cue to take off another bunch of lights and, as we assumed that these were on contactors 2 and 4, the electrician has two ways that he can do this. The first way is to push both buttons in the upper row marked 2 and 4 to the "off" position. The other way is as follows: After he has taken off his first light effect has pushed his "on" and "off" buttons of contactors 1, 3 and 6 to the "off" position, closed the Master button and switched the three-way buttons of 2 and 4 to the Master side, he then can control these by means of his Master button. This operation cannot always be done, since when the electrician changes from the line side of the three-way button to the master side he puts the lights out and then on again.

Before telling of some of the installations of this system it might be well to describe in detail the type of contactors used. In all of the installations up to the present time the contactor used is the single-pole 125-ampere with the shunt coils connected in parallel to make each two-pole contactor. The frame of the contactor is of pressed steel to make contactor very light and yet rugged. Contactors are equipped with blow-out coils in order to keep the contact surfaces clean. This is accomplished by means of a magnetic blow-out which forces the arc away from the surfaces carrying the current. This action is still further improved by use of rolling contacts. The rolling contacts have been recognized for years as the best form of contact. Some of the advantages of the rolling contacts are as follows:

1. The current is carried at the heel of the contact which is subjected to the maximum spring pressure and is kept clean by a slight sliding motion during the closing period.

2. The arcing takes place at the tip of the contact as this is the last part of the contact to separate.

3. The rolling action minimizes the bounce when closing.

4. Little chance for the contacts to become welded when together. The slight bounce which is always present when the contacts are brought together with any speed causes a slight arc to be drawn during the closing of the contact. With the rolling contact, the surfaces are quickly shifted from the tip to the heel under a very powerful leverage action, so that there is little opportunity for the arc to weld the contact together.

Installations

To the writer's knowledge there are only two installations of the remote control system in the studios of this country at the present time and both of these are the same as the one above described.

The first one installed and working was that in the Amsterdam studios in New York owned by A. J. Bimberg but rented to the Famous Players-Lasky Corp. This studio was an old opera house and was only recently remodelled into a studio.

The main stage is approximately 100 feet long and about 50 feet wide; it runs east and west. Along the west wall evenly spaced are three contactor boxes, each box containing four contactors. These boxes are mounted on the wall about 25 feet from the floor and they are reached by means of the overhead runways. This studio has three runways about 6 feet from the ceiling running the length of the stage with a number of cross runways in between. The push-button stations in the studio are permanently connected to the contactor boxes by means of 100 feet of the seven-conductor cable.

International Studio

This studio was an old dance hall until a very short time ago and then was turned into a studio. From these pictures you can

easily see the overhead runways and some of the remote control switchboards. In this studio on the first balcony is mounted the main feeder panel. From the Edison incoming line two feeds are run up to this feeder board. The feeder board is a three-panel type having two 600-ampere knife switches on each panel. Each one of these switches feeds to one of the contactor boxes. The push-button stations in this studio are similar to those described before

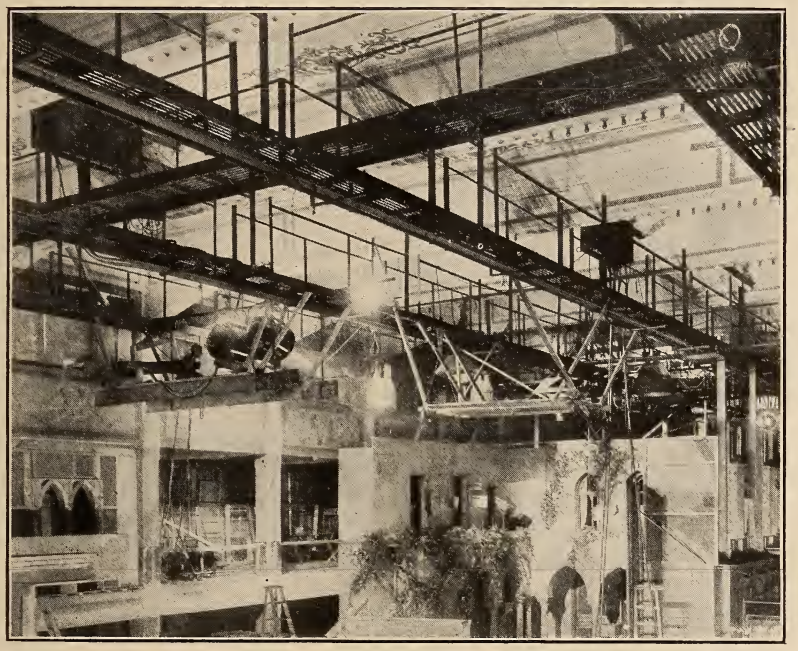


Fig. 7.

and differ from the other installation as follows: They have a train line receptacle, which means that the push-button station can be removed from the contactor box at will; also it is equipped with a jumper connecting the "off" side of the Master button of one station to the "off" side of the Master buttons of two other stations. By means of this one can readily see that one Master button could control every button on the six push buttons, which means that the 36 contactors could be closed or opened at one time simply by pushing one Master button.

These are the only two installations of any kind of remote control that are in operation at the present time, although the Metro studio in Hollywood is now planning a system very similar to the one described above and the Fox studios in New York will have one in a short time that is vastly different from this and the Famous Players-Lasky in their new studio will have a remote control system that is also different.

Perhaps at some future meeting one of the above installations, or perhaps both, could be presented in a paper that would be of great interest to the Society.

Papers Committee Report

By L. C. Porter

Gentlemen:

An engineering society such as ours is of use first to its members; next to the industry they represent; third to the public in general, largely in proportion to the amount of data that is collected, analyzed and exchanged through the mediums of convention papers, committee meetings and personal contact. Such data forms the basis of standardization, of practice and equipment, as well as development and progress.

Success along these lines means that our organization will take its place among leading engineering societies of the country, thereby becoming a powerful factor in the standardization and growth of the motion picture industry.

Your papers committee, whose privilege it is to have most to do with the securing and presenting data in the form of papers and committee reports, has felt a very keen responsibility in their work. While the results have not been entirely satisfactory to the committee and may not be to the society, we have worked hard and offer no apologies, but earnestly solicit constructive criticism and welcome suggestions on which we can act in the future.

It may be worth while to take the time to point out to you the general line of procedure which we have followed in preparing for this convention.

First: In order that the different members of the committee should not unnecessarily duplicate work a tentative program was laid out last November and different members of the committee assigned specific things to do as follows:

1. To classify the Society membership into the various branches of the industry and find out how many, if any, papers have been contributed pertaining to each branch and to make special effort to get papers on the branches having few. This classification appeared in the Pittsburgh Transactions.

2. To send a letter to the entire membership requesting them to express their preference as to subjects and authors for convention papers. This was done, but received little response.

3. To keep the membership posted from time to time as to the nature and amount of material being secured for the Montreal Convention. This was accomplished through multigraph copies of the papers committee's monthly progress report sent out by our society.

4. To study the transactions of the engineering organizations whose work overlaps that of our society, such as the Illuminating Engineering Society, and secure a resumé of papers presented before such other organizations as have a bearing on our work.

Also to get in touch with such societies and the authors of such papers with a view of securing joint papers or at least an exchange of speakers.

Unfortunately, pressure of business has prevented this work from being done. It is the hope of the papers committee to have the work taken up by someone who will have the time to carry it through.

5. To make a study of the possibilities of securing such papers as would contribute to a possible educational course. This work has been outlined to you as suggestions in connection with the report of the Educational Committee.

6. To form a new committee known as the Progress Committee whose work would be to review and report the advance of the entire art since the last convention. The very interesting report of this committee testifies to its success.

7. To prepare a definite program time schedule for the convention, grouping papers and committee reports bearing on similar topics.

8. To leave no stone unturned in securing papers that we believe desirable.

In carrying out the last work the committee has used approximately fifteen pounds of stationery, representing two thousand sheets, 8 by 10 inches, typewritten material, the majority of which is composed of dictated letters.

Nomenclature lists and the society pamphlet "Notes on the Preparation of Papers and Discussions" were sent to all prospective authors.

An effort was made to secure synopses of the various papers considerably in advance of the text. These synopses were turned over to the trade papers as fast as they were received.

Advance copies of some of the papers were prepared and sent to those requesting them and a return postal card sent to the entire membership. The only reason that advance copies of all the papers were not available is because the papers committee did not receive the texts in time. In fact, some of the papers have not yet been turned in. If they are to appear in the *Transactions,* they must be received in the very near future as we shall try and send the *Transactions* to press June 1st. The various papers are being edited for appearance in the *Transactions.* In this work no changes are made in the fundamental data or text, but the phraseology and terminology are being dressed up to conform to our recognized nomenclature and to be suited to the dignified transactions of an engineering body.

We have been unable to accept several proposed papers on account of an overflowing program. It is our hope that the authors of these papers will re-submit them in ample time for the Fall convention and that the members of the Society will assist the papers committee by personal efforts to put us in touch with men who are doing interesting work of value to our membership and worthy

of consideration for presentation to this society as a convention paper.

It is the earnest recommendation of the papers committee that in the future, individual discussions of the papers be strictly limited to four minutes. We believe that the meat of any discussion can be presented in such time. The rest of it, if desired, can be submitted in writing for use in the *Transactions*.

We also urge that stenographic reports of these four-minute discussions be taken down, edited and printed with the paper in the *Transactions*.

Supplement to Report of Papers Committee

Educational Suggestions

In considering past activities, present program and the future policy of the Papers Committee, the members of this committee have many times discussed the advisability of a complete educational program for the projectionist. With the diversified program which has been arranged for this convention, it seemed the proper time to suggest the consideration of such educational activities of the Society.

The National Electric Light Association, which is an association of all the large electrical illuminating companies in the country, has prepared a correspondence course for the education of the illuminating companies' employees. This correspondence course is sold to the employees and has met with great success, both in the results obtained, and the financial return to the association. It is the suggestion of your Papers Committee that a similar idea be carried out by this Society for the purpose of bringing before the projectionist in lessons the combined knowledge of the experts of the various lines represented in our Society. There are several handbooks available for the projectionist but none of them are in educational form.

It is the suggestion of your Papers Committee that in the future as many papers as possible be presented with the idea in view of incorporating the material therein into lessons which will ultimately be combined into a correspondence course. It is the further suggestion of your Papers Committee that a committee be appointed to consider this question and report to the convention before its adjournment.

Should such an educational program be decided upon, we would suggest that a standing committee be appointed which would be composed of representatives of each line of activity represented in this body. Each representative of the line of activity would become the chairman of a sub-committee covering that particular activity. The members of each sub-committee should be all the members of the Society interested in that particular subject. For instance, on the subject of the projection machine; one of the representatives of one of the manufacturers of a projection machine would become a member of the standing committee and automatically become chairman of the sub-committee on projection machines.

His sub-committee would be composed of all representatives of all manufacturers of projection machines who are members of the Society. It would then become the duty of each sub-committee prepare for presentation the lessons on subjects assigned to them. When such lessons have been completed they are presented to the standing committee for approval. Then the approval of the standing committee would carry it to the convention for final approval before publication.

We would suggest that the standing committee issue a prospectus of this course to determine the approximate return which would be forthcoming from projectionists or others desiring to enter such a course.

If sufficient students can be obtained, it is very possible that the Society might then maintain a general office and general secretary whose duty it should be to handle general Society business and also to handle the correspondence course.

We would suggest that the course be divided into about fourteen or fifteen lessons, somewhat as follows:

The first general subject would be the fundamentals. This subject would cover the fundamentals of electricity, of optics and illumination. These lessons would be very easy to prepare, inasmuch as there are already in existence many good courses of this nature which could be obtained with little trouble. The second general heading would be the Projection Room. This subject would be divided into such parts as the electrical considerations covering wiring, motors, motor-generators, transformers, mercury arc rectifiers, etc. Then, mechanical considerations which would cover such things as projection machines, rewinds, etc., then ventilation, its design and care, and the design and illumination of the projection room. Then we would suggest the study of applied optics, the study of the carbon arcs and the incandescent lamp. The next general subject would be the theater, its general design, location, consideration of safety and its ventilation. The next general subject might be the study of the screen, surfaces, location, cost, and a study of the causes of flicker and other peculiar effects that can be eliminated by the proper illumination and selection of screen surface. The final lesson might be on film, its care, distribution and cost.

If such a correspondence course could be prepared and properly brought before the projectionists' organizations, we feel sure that we could obtain their co-operation to such an extent that perhaps a certificate showing satisfactory completion of this course would be substituted for part of the requirements for a licensed projectionist. Such a course, if properly presented to city and state authorities, would greatly assist in standardization of projectionists' examinations and might even tend to stabilize local restrictions regarding motion-picture projection.

Respectfully submitted,

L. C. PORTER, *Chairman*

R. P. BURROWS E. L. BRAGDON MAX MAYER

Motion Pictures in Connection with Isolated Lighting Plants

By R. L. Lee

One of the most successful engineers I have had the pleasure of meeting once said that in building a piece of apparatus, he did not try to design it, but asked what it wanted to be and then made it accordingly. Evidently this was the plan under which the lamp engineers worked when they built the powerful incandescent projection lamps which are now being used so successfully. This must be the case, as if there was any way under the sun which to make a successful lamp for the universally used 110-volt service, they surely would have done it, and not built them for 30 volts.

In studying the isolated lighting-plant situation, a plan similar to this must have been followed, as the majority of the plants now being installed are 32 volts instead of 110 volts, which would have been very much more convenient from the standpoint of accessories. I do not believe that it would be interesting to you, or necessary, to go into the reasons why the average farm lighting plant is 32 volts instead of 110 volts. The fact remains that the voltage of both the incandescent motion-picture lamp and the individual lighting plant are the same, as it was due to this coincidence that I became interested in incandescent projection, and as a result of this interest, will attempt to tell you a little about the problems encountered and the situation as we have sized it up.

At the present time there are a large number of outfits equipped with independent lighting plants using incandescent projection. This may be divided into the following classes:

First: Portable motion-picture outfits for travelling exhibitors who exhibit in localities where commercial current cannot be secured, such as agricultural extension work, educational lecturers, specialty salesmen, etc.

Second: Small portable projectors for schools, churches, lodge halls, etc., in localities where commercial current cannot be secured.

Third: Small theatres having just a few exhibitions a week, in isolated districts probably using a local hall which at other times is used for other purposes.

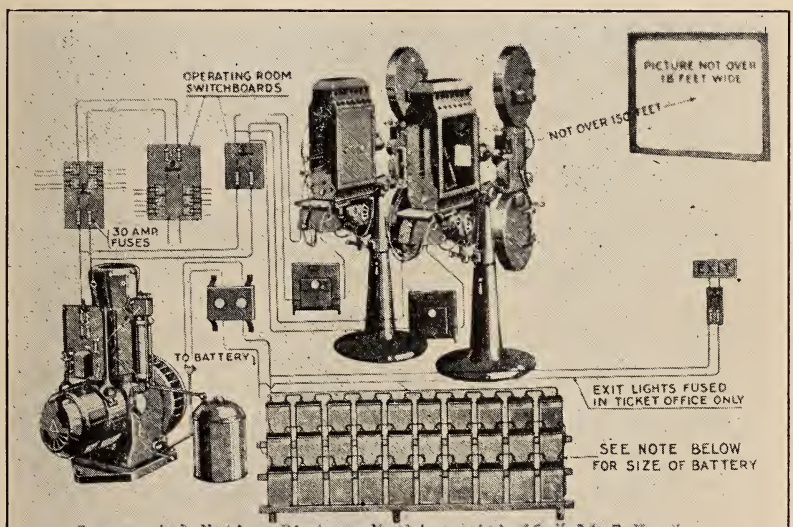
Fourth: Country theatres or small town theatres where other current cannot be secured or is so unreliable that good service cannot be extended to the patrons.

Fifth: Larger theatres where current costs are exorbitant; and

Sixth: Large town theatres wishing to protect their service from accidental shut-downs.

The speaker has been in personal contact with these various types of installations and believes that an enormous amount of work will be done in this direction in the future. It has been a rather bumpy road we have had to travel when you consider that at the beginning of this work it was very difficult to secure proper lamp houses for standard projectors, very little was known relative to the limitations of the lamps or the proper method of using them, and the care which must be taken with them, the difficulty of get-

ting projectionists to handle them properly; in fact, this work has been very discouraging at times. I believe that I will be safe in saying that the most of our difficulty was due directly to exaggerated estimates of the ability of the 600-watt 30-volt monoplane filament lamp. I am speaking of this as a result of our experience soon after its introduction. The data we had to go on was that compiled as a result of laboratory tests and which was perfectly correct, providing all conditions were ideal, that the adjustments were made accurately, proper screens used and everything in good working order. However, it was an entirely different problem after an outfit was placed in the hands of the man who knew very little about projection to start with, even though he was quite successful with carbon arc machines, who did not appreciate the necessity for careful adjustments, and where the theatres were not dark enough, where poor screens were used, etc.



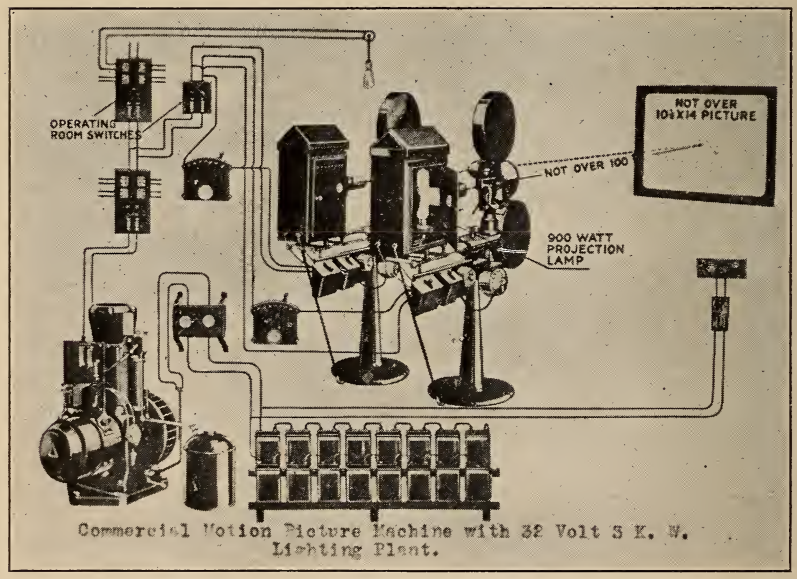
Commercial Motion Picture Machine with 66 Volt 3 K. W. Lighting Plant and Carbon Arc. (Two Batteries of 30 Cells Each Connected in Parallel Are Necessary)

After these experiences, therefore, we conducted tests in our own laboratory and then arrived at a definite sized picture and throw for the 600-watt lamp. We instructed our salesmen never to recommend a 600-watt lamp for a picture larger than 9 x 12 and a throw of 80 feet. This was, of course, conservative, as the speaker has seen various installations showing a larger picture at a greater throw very successfully, but as a result of our experience, and considering many conditions which could detract from the success of the installation, we thought it best to specify these limits and the success resulting from this practice more than repaid us for the

few installations which were not made due to not having large enough picture.

During the last four years, I have had an excellent opportunity of looking over many pieces of apparatus, and also of observing their operation in the field, and it appears to me that most of the difficulty in the various apparatus is not due to mechanical imperfection but due to the designer not considering the place in which it is to be used and the man or woman who is going to use it. One of the easiest things, and from my observation, the most unsuccessful, is taking some combination of mechanics or electricity, and attempting to force it onto the people, or in other words, to attempt to educate the public to conform to this piece of apparatus.

One of the most difficult and most successful methods of building a new piece of apparatus is to carefully consider the place in which the apparatus is going to be used and more especially



Commercial Motion Picture Machine with 32 Volt 3 K. W. Lighting Plant.

the man or woman who is going to use it, making allowances at all times for those things which the average person will not do, even though he has an instruction book as thick as the Bible.

It appears to me that the degree of perfection of any piece of apparatus is in inverse ratio to the thickness of the instruction book. I therefore believe that in the development of incandescent projection, one of the goals to work for is simplicity of construction and operation, as one of the main talking points of this method of projection is supposed to be simplicity, and the elimination of many of the duties which must be performed when using the carbon arc.

When I first went into this work about the only lighting plant made in any quantities had a capacity of 750 watts. This, of course,

limited our activities to very small theatres, the lamps taking 600 watts and with the generator running a surplus of only 150 watts, or slightly less, was left over for supplying the battery. If the battery was fully charged we figured that it would be possible with this combination to operate a theatre whose exhibitions lasted only five hours a day or less. You can readily see that this combination would be successful only in the smaller of "part time" theatres. We were therefore called upon for an outfit which would handle a larger theatre. About this time, 3-KW, 32-volt generator outfits appeared on the market and it was possible with them and the 600-watt lamp to handle larger theatres, operating an indefinite number of hours a day. Quite a number of these installations were made and from all reports are very satisfactory.

Due to the fact, however, that a limit of 9 x 12 was placed upon a possible picture at an 80-foot throw which would be entirely satisfactory, many requests appeared for outfits which would supply projection for larger audiences and theatres. It therefore became necessary to look around for something which would give us more light. We finally decided upon a 65-volt 3-KW generator with satisfactory battery and with it we could furnish screen illumination, etc., for practically any theatre excepting the larger ones. A number of these installations were made. We found after some practical experience that the light load, motors, etc., of the average theatre would consume enough current from the total output of the plant to leave only sufficient current for a 30-ampere arc. These installations were very satisfactory.

Later quite a lengthy discussion between the various lamp engineers was settled and a standard of 30-amperes, 30 volts, or 900-watt incandescent lamp was decided upon. We found that this lamp when properly installed and focused, would give us illumination equal to the 30-ampere direct-current arc. We therefore began to lose interest in the arc due to inconvenience in adjusting, etc., and concentrated in force on the 30-ampere incandescent lamp. This brings us up to the present time. At present, some difficulties are being experienced with the 30-ampere, 900-watt lamp, and it is my opinion that we had better go slowly until the lamp engineers give us their O. K. upon it.

I have given a brief history of my personal activities in this business and as a result of this experience, there are several principles which have been fortunately brought to my attention and which it seems to me are very important to the success of any engineering activity. As the only way through which the fruits of engineering may finally pass to a greater utility is through the sales force, it appears to me that the junction between engineering and sales activity is one of the most important points in any business. The salesman studies human nature and methods of overcoming prejudices and of painting pictures in the minds of his prospects and of creating a desire for the thing which he is selling. I have heard it said that if five per cent of what we tell someone else is actually digested, we are working very efficiently. In put-

ting in the 95% from my experience, I would say that there is a great temptation for the average salesman in his enthusiasm to stretch certain facts a certain amount and unintentionally make claims for apparatus which cannot be substantiated.

On the other hand, I would say that it is very easy for an engineer, when he is attempting to solve a certain problem, to get certain predetermined results, to coax the figures around a little bit toward the right direction and by accurately setting his apparatus, eliminate every feature which may detract from the maximum results and not considering that the fellow who uses this apparatus will know comparatively nothing about it, and will finally arrive at a figure entirely too high in relation to the actual performance of the apparatus.

When he turns these figures over to the salesman, who adds a little more on for good measure, the customer will be disappointed in the results he secures and it seems to me that there is nothing more discouraging to the salesman, manufacturer, and everyone connected with the project than to have a number of dissatisfied users. In fact, all the sales activity in the world attempting to combat this feature would result in failure.

I therefore believe that it is to everyone's advantage, even though we are all keyed up with enthusiasm and have accomplished wonderful things, to deal rather conservatively rather than to overestimate the results of our activities.

The salesmen, with whom I come in contact, are interested in many types and kinds of apparatus. It is therefore impossible for them to become experts in any one particular line. However, so that they may be able to understand the fundamentals of projection, I supervised the writing of a booklet made up almost entirely of diagrams and illustrations showing just what may be expected from isolated lighting plants in connection with projection. I have made a number of these illustrations into slides and will now show you an attempt to educate in a very simple manner, these salesmen.

Educational Possibilities of Motion Pictures

By B. E. Norrish

Education by the motion picture is daily being recognized as the education that counts and counts greatly. We all of us have the sense that is known as "eye-mindedness," more particularly the young. The moving picture is the simplest and easiest way known of imparting knowledge and information in an interesting and entertaining form. By means of the motion picture, every boy and girl, every man and woman, can take a post-graduate course in the greatest university of all—the University of the World.

Before the motion-picture screen, the languages of Babel tumble, for the new and great agent, the motion-picture screen, discloses a universal language and, no matter what the mother tongue of the gazer is, he understands and knows at once that which is displayed on the screen. This is the reason why the trade organizations and governments have intensively concentrated on motion-picture work during the past few years. By means of "eye-mindedness," thought impressions are being given through the motion picture to millions of every-day people. Get a people thinking along a certain line and what happens? You know as well as I do this is the way that epochal changes are brought about. By means of films, you can create and give thought impressions which will make people think Victory Bonds, More Production and all other things that are the necessity of the times in which we live. This is education and education with an end in view—the good and welfare of our people, our country, our schools, etc.

There is an old theory in psychology that a thought impression once gained never dies. It remains dormant and inactive in the brain, but will spring to life and action once there is created a sensation, or, rather, I should say, a sense perception like it again. Day after day, year in, year out, this process can be worked out in a system of distribution of films, and, as a consequence, each film or release acts as the sensation or sense perception that, by association with previous sensations, recalls to the mind, say, Liberty Loan, and with each succeeding release enlarges on and makes greater, finer and more appealing the thought of Liberty or Victory Loans.

All films can be pleasing to the eye. Education that is pleasant makes a pleasant and lasting appeal and this is the education that can be given to the people of the earth.

For instance, take scenic films. They show sport life of the mountain parklands—glorious sporting lakes and streams—holidayers having the time of their lives. Next summer holiday time, association of ideas will finally lead prospective tourists to think mountains, fishing, boating, etc., and then parks, mountains, trout, where found, come to their minds naturally as a result of the natural functions of the mind.

Ideas may be conveyed to the brain through the eye, the ear, or by means of feeling or smelling. The shortest path to the brain is through the eye, and the greatest part of every person's education

is obtained through the eye. By books the past generations have been educated. Thousands of paragraphs, miles of letters and mountains of syllables are gone over and mastered in the book studies of today. The eye is the medium whereby the monumental task of obtaining this kind of knowledge is made possible.

Take, for instance, Van Dyke's book on the mountains. Thousands of paragraphs are used to educate the novice as to what the mountain is and still the learner has not obtained a proper idea of a mountain. The motion picture at a glance brings home to the gazer or student a proper and concise conception of a mountain in all its interesting details where Van Dyke, master word painter though he is, used thousands of paragraphs to produce the same idea.

Consider what this means in child education and then realize why the motion picture is gradually but surely entering into the educational field as a valuable aid in education. Why should the teacher, for instance, have to take hours in teaching a boy about his country and then, as is shown by the quarterly examination, find out that much of his or her efforts have been useless? There is a reason clear and simple for this failure. The scholar has had to take into his or her mind by the ear the impressions which the teacher has been trying to give and also he has had to laboriously pore over the printed page cramming in his lesson.

It is a remarkable fact that seven-eighths of all knowledge is only acquired and understood after there has been flashed before the mind mental pictures by the millions. Every conception is only arrived at and understood after the mind has seen in mental pictures all the things that go to make up the conception or thought. For instance, a child does not master quantity or number until he has pictured in his mind a series of pictures. Let us take 4, for example. Until he has mentally seen that 2 and 2, or 3 and 1 make four, he does not really know what 4 is.

Seven-eighths of all acquired knowledge is thus obtained, the remaining one-eighth is simply mastered by memory or cramming without mental pictures being seen. This is weak and faulty knowledge. Picture-making thus forms the basis upon which real knowledge is acquired. Hard work it is too. The motion picture steps in now and, by natural law, performs a function which at once enables the mind without effort to take hold of and hold fast on its inner or mental picture, thus removing the laborious and tiring processes which the mind has had to undergo to get solid and well-balanced conceptions, or knowledge in the past. Motion pictures, therefore, naturally fit into all educational work and, as time passes on, the greatest function that will be performed by motion pictures will be that of teacher and mentor.

Let us just consider for a moment the course in geography. I know in my time I had to get my thought impressions of natural geography by cramming definitions. For instance—a mountain was described as a very high hill. There was a hill at home and I can remember today how my imagination piled up solid earth on

top of that very hill to get my impression of a mountain. What a farce the whole thing really appeared to me in after years when I actually saw and climbed a real mountain! By means of the motion picture at a glance a boy may get a correct and positive idea of a mountain.

What an awful job it was to master the industries of the countries of the world in the old days. Hours and hours of work, and then not half ready, I went with fear and trembling to the examination. What a Godsend would the good industrial pictures now produced have been at that time!

To illustrate, with the motion pictures we can now go to Vancouver Island, cut down a giant of the forest, transport it down the skidway to the Pacific, where it is made up with many others into a Davis raft. We can see it towed to the mill and there cut up into lumber, and then taken by scow to the railhead whence it lands in Toronto where the lumber is used to build aeroplanes. All the processes of manufacture are followed, and finally, the finished product takes its flight in the air, a beautiful aeroplane. Thus the student can actually see the workers of this industry at work and, in so doing, actually see the province or territory whence the natural product came. A teacher could talk for hours on this subject and still the student would only have but a hazy idea of the subject because he has only been taking in the knowledge through the ear, whereas by the film story—and there are many wonderful industrial films available today—he actually has had a living experience, for he has himself actually travelled to Vancouver Island, seen the lumber men at work and journeyed on until the product, a British Columbia spruce, is used in the manufacture of an aeroplane in Toronto.

And so it is with hundreds of other subjects. The student can go by the film story to the salmon fields, to the shipyards, to the grain fields, the elevators, fishing belts, the fruit valleys of the world, the mountain parklands, the summer resorts and playgrounds, water power areas, where he sees the processes by which hydro-electrical energy is obtained and applied, the irrigation areas where he sees for himself the how and where and why of irrigation. Millions of words, thousands of hours of hard plugging would only have given him a superficial knowledge of these subjects if he had never had the opportunity of living experience which only can be had by visiting the spots in question in body or by being carried thither by the picture story on the screen.

Give a boy or girl this opportunity, give him an examination, and compare the results with the answers that will be given by boys and girls who have only had the conceptions that are obtained by the book or spoken word and the results will be astounding.

The motion picture attracts the boy or girl student. It holds his interest. He journeys to the subject he is to study. He sees it. He sees what it looks like, what it does, what it is used for, and Excelsior! He is a boy with knowledge and information because he is really an explorer and traveller. This is why I base my claim upon the fact that as an educator the motion picture has come

to stay or plan an ever-increasing and more important part in the education of the race.

By means of the films, patriotism can be developed, love of country intensified, proper conceptions with regard to each portion of the country obtained and, best of all, a proper understanding of the relations of each individual part of the country to the whole and of nation to nation.

No college today has a complete equipment unless it has *a* picture machine and educational films. This is being recognized in Canada from coast to Coast.

Society of Motion-Picture Engineers
Report of Committee on Progress

By A. R. Dennington

A review of the motion-picture industry during the past six months or year shows a number of improvements which have been made and which help to bring the motion-picture industry into greater prominence than before. The object in writing up this review is to summarize briefly some of the notable steps which have been taken by the manufacturers of equipment and the producers of film. It is not within the province of this paper to go into detail regarding any of the matters taken up, as these subjects will in most cases be covered by other papers prepared by those who are more familiar with the details than are the various members of the Committee on Progress. It is hoped that the report may be of value in merely pointing out the general lines of improvements. It is to be feared that some fields may not have received the attention which they merit because of the impossibility of securing from those interested in different lines all of the information which would have proven helpful. However, the Committee wishes to thank the various contributors who have supplied the information which has been used as a basis for this paper.

Standard Motion Picture Machines

Among the developments which have appeared on standard motion-picture machines, and which help to make these machines more easily operated and more effective, are the following:

An arc lamp with the carbon placed at 90° to each other, and having a magnetic field to control the arc, has been developed, tested out, and found to be very efficient. The increase in efficiency is due to the fact that the crater of the positive carbon can be made to squarely face the condenser. The magnetic field used keeps the arc centered on the positive carbon so that the crater does not wander around, and the carbon burns off uniformly. The small negative carbon used can be brought entirely outside of the angle which includes the condenser, so that there is no shadowing of any part of the screen. It is estimated that a 35-ampere arc on the 90° arc lamp is fully equivalent of a 50-ampere arc on the older type of mechanism.

The difficulty which is experienced by some operators in maintaining an arc at the proper focus of the optical system and keeping it steady so as to produce a clear screen, will be entirely overcome by the use of arc controllers which are now being manufactured and placed on the market. The arc controller has been used for some time past in a few instances, but has never been developed to such an extent that it has become a usual part of the equipment. New designs of arc controllers are such that the mechanism has been considerably simplified, and the action is therefore more reliable and the equipment can be sold at a lower price, thus making it available in many theatres where in the past it would not have been considered. The proper focusing of the arc is such an impor-

tant feature of good projection that the new arc controllers will undoubtedly prove of special value in making possible a higher standard of projection.

The development of motion-picture theatres costing millions of dollars has emphasized the fact that in the past no projection equipment was available which adequately matched the completeness of equipment used in all parts of the house excepting the projection room. In order to overcome this lack of co-ordinate equipment there has been a tendency to develop complete projection units or complete units which will, when properly installed in the projection room, enable the operator to give better service than has been possible in the past. These units are something in line with the complete units suggested by Mr. Jenkins in a paper before this Society some two years ago. The complete projection unit equipment includes extra projectors, which can be used in emergency if there is an accident to any one of the machines. The generating equipment is now installed in duplicate, which is a practice to be recommended as it enables the operator to clean and oil one of the machines and have it ready for service while the other is running. Where only one machine is used there is little time for adjustment and repair, with the result that the machine deteriorates more rapidly than if it had proper care, and there is also risk that it may not be in operating condition when required for the regular performance. The installation of duplicate equipment is a step in the right direction, and it marks a development which has come into much greater prominence in the last year than heretofore.

As an aid to the projectionist in determining whether or not the arc is operating properly a reflector and lens has been arranged so that the image of the arc may be thrown on the walls, ceiling or floor of the projecting room. This enables the operator to tell at a glance the general condition of the arc without glancing through the peep hole in the lamp housing. The image of the arc is not so bright as to cause discomfort to the operator and he is therefore able to keep his eyes in better condition for properly focusing the picture on the screen and giving the patrons best results.

In order to determine the time when change-over should be made from one machine to another, a counter has been developed which shows the number of feet which have been run off the reel. This equipment is extremely simple in construction and reliable in operation. It is necessary only for the operator to set the dial at zero when a new reel is installed. As each foot of film is run off, the counting device, which is of the cyclometer type, advances one numeral. There are other modifications of this same device, and it is of service to the operator in adjusting the speed to run his film in the specified time, and also for determining the length of reel. The present tendency of splicing two 1,000-foot reels together in order to reduce the number of change-overs from one machine to another has brought out the importance of having as nearly as possible uniform tension on the film. With a 2,000-foot film the tension at the start with the usual equipment is very much greater

than is necessary, and this results in undue wear of the film. If the tension at the beginning is made small there will not be sufficient tension to insure that the filament will be taken up when the reel is nearly full. The difference in tension has been overcome in the new type of reel which has been developed. The new reel has a loose wooden hub on which the outer metal part slides. The hub is turned and when the reel is empty there is sufficient friction between the hub and the metal rim to take up the film without undue strain. As the film builds up on the lower reel the weight increases and the friction also increases, thus giving a practically uniform tension, depending upon the weight of the film on the spool for the pull which is required.

Another refinement which has been noted in standard motion-picture machines is the use of a small incandescent lamp placed inside the lamp housing. This lamp can be lighted when it is necessary to change carbons or make other adjustments on the mechanism. This insures that the operator will have ample illumination inside the lamphousing without the necessity of using a portable light, which is more or less troublesome to handle and at best can be considered only a makeshift.

Arc Lamp Carbons

Carbons for the arc lamps used in picture projection were prior to the war imported at the rate of approximately twelve million per year. These carbons were manufactured under labor conditions which made it impossible for American manufacturers to compete, and the industry was developed only through the experimental stage. However, when the war broke out in 1914 the importation of carbons soon ceased and the American manufacturers were called upon to supply the carbons for the entire trade in this country. This meant the construction of large plants, the development and installation of special machinery, and the perfection of manufacturing processes. The result has been very gratifying, as the American made product of today is far superior to the imported carbons of a few years ago. The superior results which are obtained are due to a number of points which merit attention.

The upper carbon for the direct current arc is now composed of a hard specially constructed electrically conducting material, surrounded by a heat-insulating compound embedded within a star-shaped core. The core enables the arc to be centered almost the instant the current is applied, and the old system of burning the carbons for five or ten minutes in order to get a proper crater has been entirely discontinued because unnecessary. The carbons are also made up so as to have a maximum current carrying capacity, so as to increase the illumination per unit of crater area, and enable a firm arc to be maintained with very few adjustments.

The negative carbons on direct current arcs are now usually small in size and are plated with metal so as to increase the conductivity. The negative carbon acts merely as a conductor to carry away the current, and it has been found that the smaller this con-

ductor can be made, the better, and the less is the interference of the light from the positive crater.

Special carbons have been developed which are usually sold in sets, consisting of one 12-inch upper carbon and two 6-inch lower carbons. It is extremely essential that the carbons should be used in the manner designated, as the composition of the carbons is such as to give best results only when the upper carbon is used in the upper holder and the tip presented to the condenser. In the manufacture of this combination a special chemical water glass is used in the upper carbon and a small amount of rare earth in the lower carbon. The yellow tinge in the beam which has heretofore been characteristic of many of the alternating-current arcs, has thus been eliminated, and the picture is projected with a clear bright white light.

There is a very marked tendency toward the use of high current arcs. Where the standard a few years ago was for 35-50 ampere arcs, the present demand is for arcs rating at from 75 to over 100 amperes. There is a possibility that with the growing use of the 90° arc these higher current values may be somewhat reduced.

Gas-Filled Incandescent Lamps for Projection

The growth in the use of incandescent lamps for projection purposes has not been rapid because of the necessity of further development work on various points in the lamp and equipment. One of the most notable changes has been in the lamp itself and has to do with the interior construction.

Experiments have shown that with the filament supported in an upright position, and anchored firmly in place, there is a tendency for the coils to warp because of the expansion and contraction as they are heated and cooled. In order to overcome these difficulties the coil has been suspended from the leading-in wires and expansion joints placed in the lower supports so that the filament is free to expand and contract, but is held in correct position and alignment by the supports.

The lamps for the smaller or portable motion-picture machines have remained with very little change, though there is a tendency to use filament of monoplane construction wherever possible, as the effects produced on the screen are better than with the more usual types of filament arrangement. There are also proposed some changes in bulbs to meet the requirements of the small motion-picture machine. Most of these machines require bulbs with fairly small overall dimensions, and in many cases tubular bulbs are essential.

Electrical Equipment

The electrical equipment used in motion-picture projection has been so well standardized in the past that the last six months or one year has shown very little change. There have been developed and placed on the market a number of constant current regulators for use with incandescent projector type lamps, and controlled

regulators have also been perfected so as to give closer regulation and more accurate adjustment of the current. No changes have been reported on the usual type of projection room equipment, such as motor-generator sets, regulators, etc.

Optical Systems

The optical systems have remained unchanged where arc lamps are used. The increasing length of throw in the larger theatres results in a demand for larger objectives. The mountings of lenses are standardized and the manufacturers of lenses are preparing to meet the demand for larger objectives.

For incandescent lamp projection there are two systems of condensers which are commonly used at this time. These two systems are the plano convex condenser system and the prismatic condenser system. Both systems seem to be well established and doubtless will continue to be used. In the smaller portable machines there has been a tendency to use prismatic condensers of small type and short focal length.

Studio Lighting

In the methods of studio lighting there has been reported no change in the period since our last meeting. The systems used are the arc lamp, mercury vapor lamp, and in some cases the incandescent lamp. Improvements in the arc method of illumination of studios are in the carbons and in the use of large currents to get more powerful units. Mercury vapor lamps have been improved so as to be moved and directed more easily. Incandescent lamps and lighting systems for studios have not been appreciably modified and are commonly used in conjunction with other systems of illumination to secure special effects.

Tests of Screen Illumination from Motion-Picture Projectors

By W. F. Little

Field illumination for motion-picture projection may be studied by several different methods. Here the experience of the Electrical Testing Laboratories may be of some service and it is the purpose of this paper to present some notes on such tests.

In order to make comparisons between the different methods of study a constant light source or the incandescent lamp was used.

Intensity

As the light intensity in the field is more or less a function of the field area, the problem in this connection is to determine the flux in lumens through the objective lens.

Uniformity of Field

The field brightness may vary considerably without greatly affecting the appearance of the picture for the reason that the variations in intensity are gradual.

Test Methods

As all the light passing through the objective lens reaches the screen, the quantity of light may be investigated either on the screen or at the objective. Photometric measurements may be used to determine the field intensities by making measurements at the screen. The usual practice is to divide the entire field into equal areas and make measurements in the center of each. The nearer the observation area conforms to the area to be investigated the more accurate is the integration secured. Therefore, in order to cover the entire field these areas should be either large, or numerous. If the observed portions comprehend too large an area, the light intensity variation may be lost sight of. If the measurements are made at the objective, the results will bear no relation whatever to the uniformity of the field. Therefore, the testing may resolve itself into two distinct methods; first, that of the measurements of light upon the screen, and second, that of the measurements of light at the objective. The first may be again subdivided (a) including relatively few measurements, each measurement integrating over a comparatively large area, and (b) a large number of measurements, the average of which produces a close approximation of total flux and a fair index of uniformity; this latter method gives the most complete data.

The optical bar with which the experiments were made consisted of objective, aperture plate, condenser, lamp and spherical mirror, all located as in a motion-picture projector. An illustration of this equipment appears in the Transactions of this Society, No. 6, Fig. 16, page 68.

The photometer employed in tests of field illumination is so designed that the inequalities in field brightness throughout the observed area are obliterated, the surface appears uniform, and the brightness equal to the average brightness throughout the surface.

The other test apparatus used in the investigation was as follows:

Throw	60 feet
Objective lens	E.F. 5.5, D.2.5, *F*.2.2
Aperture	$\frac{11}{16}$ x $\frac{29}{32}$ inches
Condenser lens	2½ x 6½
Lamp	Mazda — 900 watt, 30 amperes
Spherical mirror	2¾ inches O.R.C.
Field area:	10 feet x 7 feet, 9 inches

With an incandescent light source, slight variations in symmetry of filament or filament alignment may produce a variation in light intensity upon the screen. Therefore, it is advisable to explore the entire field. An accurate alignment of the apparatus is highly essential, therefore the entire test procedure may be simplified if the test-plate and photometric equipment are fixed and the projector is adjustable.

When using a fixed test-plate and photometric equipment, the projector may be accurately aimed by the aid of a telescope and cross-hair. The telescope should be mounted over the pivot about which the projector turns and focussed upon a chart plotted on cross-section paper. A diagram of the field may be readily plotted to scale upon this cross-section paper and mounted in any convenient direction at such a distance from the telescope that the angle subtended by the chart is exactly equal to that subtended by the field. The centering of the cross-hairs upon the center of each test area as shown on the chart will bring the corresponding field areas to the proper position on the test-plate.

If the light source be an arc, the distribution of light intensity over the screen should be fairly symmetrical for the reason that the major portion of the light emanates from the small round crater. However, because of the light fluctuations when studying projection with an arc lamp, it is advisable to use two photometric equipments, one for observing the center of the field, the other for exploring purposes making the measurements simultaneously. In this case it is essential to keep the projector and one photometer fixed. The readings taken with the exploring photometer may then be corrected to the fluctuations of the arc as secured by the fixed photometer.

For the purpose of study, photometric measurements were made on the screen surface, dividing the field first into 16 and then into 256 equal rectangles.

16-Point Method

When dividing the field into 16 equal rectangles, fairly adequate integration should be secured if the observed test surface represents at least 40 per cent of the area of each rectangle.

The ellipse in the upper left rectangle on plate 1 shows the relative size of the observed area as compared with the rectangle.

256-Point Method

In dividing the field into 256 rectangles rather than 16, the observed area may be relatively smaller with respect to the rectangle and still render good results. As the light intensity falls off toward

10.0	11.1	10.9	9.4
10.5	11.6	11.0	9.8
10.0	11.6	11.0	9.4
8.6	10.1	9.1	7.5

Fig. 1.—Measurements Made by 16-point Method.

10.0	10.7	11.0	10.7	10.9	11.1	11.4	11.5	11.3	10.8	10.6	10.1	9.9	9.4	8.7	6.9
10.7	10.8	10.7	11.0	11.1	11.1	11.7	11.8	11.6	11.2	10.8	10.2	9.9	9.7	8.9	7.7
10.3	10.8	10.9	11.1	11.2	11.5	11.7	11.6	11.8	11.2	10.9	10.7	10.6	10.2	8.9	7.4
10.3	11.2	11.4	11.5	11.6	11.9	12.4	12.4	12.1	11.5	10.8	10.7	10.7	10.5	9.4	7.2
10.9	11.2	11.3	11.2	11.4	11.6	12.3	11.9	12.0	11.5	11.1	10.9	10.7	10.2	9.4	7.6
10.3	11.2	11.1	11.4	11.5	11.6	12.0	12.0	11.9	11.5	10.9	10.6	10.4	10.2	9.5	7.8
10.6	11.6	11.7	11.5	11.4	11.4	11.6	12.0	11.7	11.1	10.9	10.6	10.6	10.3	9.4	7.9
10.8	11.1	11.4	11.1	11.5	11.6	11.7	11.9	11.7	11.4	11.1	10.8	10.7	10.3	9.4	7.8
9.7	11.2	11.2	11.3	11.4	11.6	11.7	11.9	11.6	11.4	10.8	10.4	10.2	9.9	9.4	7.6
9.8	11.1	11.1	11.1	11.2	11.3	12.1	12.1	11.8	11.5	10.6	10.5	10.0	9.8	9.1	7.6
10.4	10.6	10.6	10.6	11.0	11.1	11.3	11.5	11.5	11.1	11.1	11.0	9.7	9.5	9.0	7.4
9.0	10.2	10.2	10.3	10.6	10.9	11.0	11.3	11.4	11.0	10.3	9.9	9.4	9.1	9.1	6.9
8.7	9.9	9.9	10.1	10.6	10.7	10.7	10.7	10.7	10.3	9.6	9.0	8.8	8.6	8.4	6.8
8.4	9.3	9.4	9.6	9.9	10.3	10.4	10.5	10.2	9.6	9.1	8.4	8.2	8.0	7.8	6.7
6.9	8.2	8.2	8.8	9.3	9.1	9.4	9.3	9.1	8.4	7.9	7.8	7.7	7.4	6.9	6.0
5.6	6.9	7.3	7.4	7.9	7.9	8.2	8.1	7.7	7.1	6.8	6.4	6.7	5.9	5.3	4.7

Fig. 2.—Measurements Made by 256-point Method.

the edge of the field, the 256-point method should show somewhat lower light flux than the 16-point method as the observed areas do not quite reach the screen edges. With a field of approximately 8 by 10 feet, the outer rows in the 256-point method are 2 inches or less from the edge of the field.

Measurements at the Objective

As previously stated, all the light passing through the objective falls within the field. Therefore a single photometric measurement of light flux at the objective may represent the flux upon the screen.

The measurement of light at the objective is not as simple as might at first be expected for the reason that the flux density is very high; through an aperture of approximately 1.5 square inches, a flux in the neighborhood of 800 to 1,500 lumens may pass. Assuming 800 lumens, the flux density would be 530 lumens per square inch or 76,500 lumens per square foot, which is equivalent to the illumination produced by a lamp of 76,500 candlepower at a distance of 1 foot.

In making these measurements, a photometer and a 3-inch velvet lined tube 24 inches long were used. At either end of the tube white diffusing plates were placed and a light filter which served to correct the color of the light to that of the comparison lamp in the photometer.

The two diffusing plates which were separated by 24 inches were employed for the purpose of reducing the light intensity to a value which could be conveniently measured.

The photometer was calibrated in connection with this tube in terms of the 16-point method, and this standardization was maintained by retaining several incandescent lamps as standards. These lamps are burned somewhat low in order to increase their life. It was found by experience that this method of maintaining the standardization was very reliable.

Table 3 shows a series of measurements where the same standard lamp was used, refocussing it four different times. Between set-ups the lamp was removed from the socket and the spherical mirror location changed. The maximum variation from the mean is plus or minus ¾ of one per cent. Another method of verification is to project the beam into an integrating sphere, thus determining the total flux.

Table 3. Reproducibility of Results of the One-Point Method Using a Standard Lamp

Per Cent Lumens on Screen	
Without Mirror	With Mirror
100	162
101	164
101	165
101	162

Analysis of Results

A comparison of the three sets of determinations, namely the 16-point, the 256-point and 1-point methods, shows them to be

in substantial agreement. However, in this particular test, the standardization of the photometric equipment used for the one point, measurement was made to agree with the result as found by the 16-point method; therefore they should and do agree. This is shown in Table 4 where a number of lamps were measured by both methods, the photometric equipment for the 1-point method being standardized with an incandescent lamp.

Table 4. Comparison of 16-Point and 1-Point Methods

No. of Lamps Measured	Lumens on Screen 1-point method Average	16-point method Average
10	838	835
6	728	726
6	589	594

The 256-point method is slightly low, though it should be expected that the results would be even lower by reason of the proximity of the outer rows to the edge of the field, the outer row being considerably lower than the average. The test results of both the 16-point and 256-point method (plates 1 and 2) show that the plane of the filament is not exactly normal to the projector axis, since the lowest intensity is found in the lower right quadrant, the highest intensity in the upper left quadrant. The average of each quadrant by the 16-point method and that of the 256-point method is shown in table 5.

Table 5. Average Flux in Quadrant

	16-point method	256-point method
Upper Right	10.0	10.2
Upper Left	10.8	11.3
Lower Right	9.3	8.9
Lower Left	10.0	10.0

By a study of the 256-point method, it will be seen that the field uniformity bears little or no relation to the disposition of the filament coils or coil image. It might be expected that seven distinct vertical high ridges would be found to conform with the filament coils and coil images whereas the highest intensity is in the center of the field with a more or less gradual tapering off toward the edges with a greater taper toward the sides than toward the top and bottom. The superimposition of the filament image between the filament loops fill up and smooth out the field intensity.

An independent verification of the 1-point method was obtained by securing the transmission of the diffusing plates in the tube, the results of which showed the values for the 16-point method 4 per cent high. Again this would indicate that the 16-point method gives results which are slightly high.

Intensity Increase from Mirror

The spherical mirror increases the screen illumination by filling up the gaps between filament loops and increasing the filament temperature by reflecting heat upon it. With a total increase of 70 per cent in screen illumination, 46 per cent may be attributed to the extension of the light source due to the image and 14 per cent to the temperature rise in the filament.

In table 6 will be found data showing the increased illumination with the use of the spherical mirror.

TABLE 6. PER CENT INCREASE DUE TO MIRROR

Average of 10 lamps selected at random	67%
Minimum	65%
Maximum	73%

The effectiveness of the mirror decreases with the life of the lamp; this is caused by the distortion and spread of the filament coils and the inability of the mirror to fill up the gaps.

INTENSITY CHANGE WITH CHANGES IN ELECTRICAL VALUES

During the test the current was supplied from storage batteries so that the necessity for correcting the variation in electrical values was eliminated. However, the attached characteristic curve, Plate 3, illustrates the variation in screen intensity resulting from variation in electrical values.

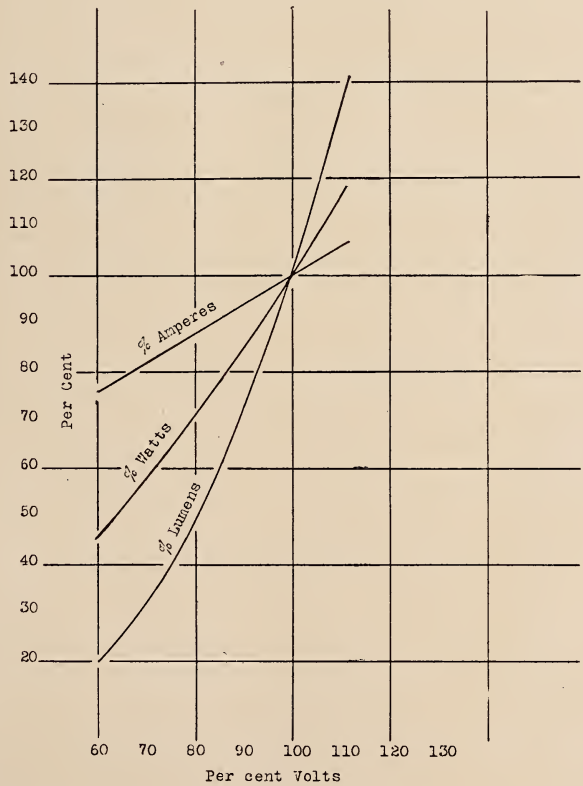


Fig. 3.—Characteristic Curve Showing Variations in Screen Intensity.

Screen Flux in Relation to the Lamp Temperature

In general other things being equal, the test results show that the screen intensity varies with the filament brightness. Many apparent conflicting results are found though these may be attributed to filament irregularities.

Focusing

Supplementing results shown in the paper on "Some Considerations of the Application of the Tungsten Filament Lamps to Motion-Picture Projectors" appearing in the transactions of this Society, some experiments were made on the focusing of the lamp and spherical mirror. Mr. Porter and Mr. States show diagrams which indicate the change in screen lumens due to spherical mirror and condenser being moved from the correct position.

Assuming the correct position for the condenser, aperture plate and objective lens, some experiments were made to determine the position for the lamp filament and spherical mirror in order to secure the highest field intensity. The method employed was to so place the lamp filament as to produce a filament image on a plate placed at different positions in front of the objective lens. This plate was moved from a position almost in contact with the outer lens of the objective to a position several inches in front of the objective, each time positioning the filament so that its image was projected with the best definition obtainable. In each position of the lamp the spherical mirror was placed so that the filament image was dovetailed between the filament loops. In table 7 will be found the results of this study. It indicates that a considerable variation in the position of this screen will not materially change the quantity of the projected light.

Table 7

POSITION OF PLATE	PER CENT LUMENS
Normal	100
Distance decreased ¼ inch	99
" " ¾ "	99
" " 1½ "	97
Distance increased ¼ inch	99
" " ¾ "	100
" " 1¼ "	99

Conclusions

Basing the conclusions upon test data, the one-point method produces satisfactory results for quick and accurate comparison of light sources where field uniformity has previously been determined. Where a study of uniformity is important, the 16-point method gives reasonably complete data. Where the full information is desired with respect to screen flux, uniformity and alignment of the filament and optical parts, a method employing a considerably larger number of test areas should be used.

The Tinting of Motion-Picture Film

By G. A. Blair

The problem of suitably coloring the motion picture is now occupying the attention of many serious workers in the industry. Some few years ago the plain black and white picture was in itself a sufficient novelty to interest the public and color was of no particular consequence, providing the story was sufficiently interesting. Times are changing, the public is growing more exacting in its requirements and the demand for color is evident from the fact that from 80% to 90% of the film now being produced is tinted.

In spite of the success attained by many workers in producing multi-color pictures by purely photographic means the expense involved reduces the prospect of the natural color picture coming into universal use for some time to come, so in the interval the majority of film will be colored by improved methods of tinting and toning.

Tinting

Tinting, as usually understood, consists in immersing the film in a solution of dye which colors the gelatine, causing the whole picture to have a uniform veil of color on the screen, though there are other ways of producing the same effect as follows:

1. By the use of color screens at some point in the path of the beam of light in the projector. The color screens may consist of sheets of colored glass or of dyed gelatine similar to the usual photographic filters, conveniently mounted in a circular rotating holder placed in front of the projector lens. This method is very satisfactory if a long run of film is to receive the same tint, though if the tint has to be changed between scenes some mechanically operated arrangement is necessary.

Interesting effects may be secured by using a compound filter composed of two or more sections placed at a suitable distance in front of the lens, so that one color will diffuse into the other on the screen.

2. By "flood lighting" the screen, which consists in throwing beams of colored light onto the screen from the wings. This method is fairly effective but necessitates the assistance of one or more operators.

3. By coloring the film base. Apart from the manufacturing difficulties involved in producing such film the limited number of prints which could be supplied would not warrant the demand for the infinite variety of shades and tints employed by various producers.

4. By coloring the gelatine by means of inorganic salts. This interesting method depends upon the fact that certain inorganic metallic salts, such as uranium and iron ferrocyanides, lead sulphide, etc., in the colloidal condition are highly colored. The method of tinting consists in precipitating the colored salts within the gelatine by first immersing the film in a weak solution of—say, uranium

nitrate, rinsing and then placing in a weak solution of potassium ferrocyanide and washing. The depth of tint depends on the concentration of the solutions and on the time of rinsing before immersing in the ferrocyanide. The color does not bleed but in view of the labor involved and the limited number of colors available the method is inferior to that of tinting with dyes. (See *Motion Picture News,* December, 1918, p. 3941.)

5. The method of tinting with dyes is the most satisfactory and is almost universally employed. The dye can be applied to the film by means of application rollers or by floating the film across the surface of the dye or by spraying, though the method of dipping, as in development, is in most general use.

Success in tinting depends on the correct choice of dyes and the correct methods of their application.

Choice of Dyes

Dyes are of two kinds, acid and basic, depending on their chemical composition, acid dyes being alkali salts of organic acids while basic dyes are the chlorides, sulphates, etc., of organic bases. The two classes of dyes may be distinguished as follows:

(a) When a solution of an acid dye is mixed with a solution of a basic dye, both are mutually precipitated and come out of the solution, and this property is made use of in testing whether a dye is acid or basic. It is simply necessary to add a solution of a known basic dye; for example, methyl violet to the unknown dye solution, and observe if the solution remains clear (indicating a basic dye) or becomes turbid (thus indicating an acid dye).

(b) Another method consists in immersing the edge of a piece of blotting or filter paper in the dye solution. In the case of a basic dye, as the color runs up the paper, a colorless band precedes the band of color as if the paper were filtering the water from the dye, while with an acid dye no such line of demarkation is noticed.

(c) Another interesting property of basic dyes is that an acid solution does not usually dye gelatine as rapidly as a neutral solution, while with most acid dyes the rate of dyeing is considerably increased by adding acid.

None of the above tests is absolutely conclusive, though in the absence of the more refined chemical tests if all three confirm each other they may be considered as conclusive.

In view of the opposite nature of acid and basic dyes, it is obvious that if several dyes are to be mixed one with another to produce intermediate tints they must all be of the same class. Since the number of acid dyes of suitable color is far in excess of the number of basic dyes, thus giving greater selection, and since acid dyes are usually more stable to light, they are the most suitable for tinting.

Properties of Acid Dyes

Dyes suitable for tinting should possess the following properties:

1. The dye should not "bleed" to any considerable extent when the film is washed; in other words, the rate of removal of the dye should be slow and only a slight amount should wash out in a period of—say five minutes.

In tinting, bleeding is of very considerable importance, since during the period between rinsing after dyeing and the placing of the film on the drying racks, any drops of water on the surface of the film become more or less saturated with dye, and these, after drying remain as spots and irregular markings which are very apparent on the screen.

It is possible in some cases to modify this bleeding by an acid "stop-bath," or by adding acid to the dye-bath, though it may be considered a general rule that the bleeding of a dye is a property particular to itself. In selecting dyes it is therefore necessary to choose only those whose propensity for bleeding is a minimum.

2. The dye should not be precipitated by alum, calcium (lime) magnesium, or iron salts. A large number of dyes are readily precipitated by these salts, the result being that if the water supply contains a slight amount of—say alum or calcium salts, or if the film is for any reason not thoroughly washed after leaving the alum hardening fixing bath, the dye precipitates in the tank as a sludge and produces a spotted effect on the film. Hard water, which may contain carbonates, bicarbonates or sulphates of calcium and magnesium, is therefore liable to give trouble with unsuitable dyes. The use of distilled water for mixing the dye solutions will partly eliminate the trouble, though a supply of distilled water is available in very few film laboratories.

In many localities the water supply is treated with compounds containing alum and iron salts to precipitate vegetable colloidal matter in suspension though after settling, the water still contains alum in solution, and also any previously dissolved salts, which cause the trouble.

The dyes recommended below are not readily precipitated by alum, calcium, magnesium, or iron salts and a large number of dyes while otherwise suitable for tinting film have been rejected because they failed to stand this test.

3. The dye should not be "dichroic" or change color (hue) on dilution, otherwise it is difficult to repeat results and match any given tint. The dye should also be fast to light even under the heat of the projector, otherwise local fading would result in patchiness on the screen.

4. The dye solution should not froth readily, otherwise foam accumulates on the surface of the tank, especially when the drum system of tinting is employed and clings to the film even after rinsing.

5. The dye should not be affected by the acid-fixing bath since

any fixing solution accidentally splashed thereon will destroy the dye immediately. Great importance has not been attached to this test since hypo should never reach the tinted film. It has been impossible to collect a complete set of dyes which will pass this test, though in choosing between two otherwise satisfactory dyes the one affected by hypo has been rejected.

6. The dye should be inert and not attack the gelatine coating of the film even after incubating for 24 hours at 212 degrees F. This is of fundamental importance otherwise the film becomes brittle and its wearing qualities are impaired.

Brittleness of Film.

Complaint is sometimes made that film is lacking in physical properties, and in many cases this is apparently so, but due to no fault in manufacture. Projecting conditions have changed. Whereas 20 to 30 amperes was considered sufficient for projection, owing to longer throws necessary in the larger theatres, many houses are using considerably over 100 amperes. In the interval between successive showings the film has not time to cool, the result is a continual baking of the film which affects its flexibility and with other factors produces brittleness. These factors may be tabulated as follows:

1. The corrosive action of the dye itself. Several dyes when employed at a concentration of 1% attack gelatine readily at 70 degrees F. and vigorously at 80 degrees, especially in the presence of small amounts of acid, producing a marked softening and often partial dissolution of the film. The effect is roughly proportional to the concentration of the dye and to the temperature, and varies with each individual dye.

Experience has shown that the gelatine coating of film which has been softened in this way by the dye becomes brittle on subsequent projection. The effect is due partly to the particular chemical constitution of the dye itself and also to the impurities mixed with the dye. Commercial dyes are prepared by "salting out" the dye by adding common salt, sodium sulphate and other chemicals to the dye solution so that unless the dye is subsequently purified it contains sodium chloride or sodium sulphate with more or less iron which has a tendency to harden the film considerably.

2. The hydrolising action of acid which in many cases is added to assist in dyeing. The addition of acid to a solution of an acid dye usually has the effect of increasing the rate of dyeing while in the case of a basic dye the rate of dyeing is diminished. With acid dyes, acid also tends to fix the dye in the gelatine and therefore diminish the rate of bleeding. In such a case only a volatile acid, such as acetic acid, should be used, since this will mostly evaporate on drying. If a solid acid, such as citric or tartaric is used, this remains in the film on drying and under the influence of the heat of the projector, especially in damp weather, the acid soon begins to decompose the gelatine film.

The effect of acid on gelatine is readily seen by adding a few pieces of gelatine to a strong solution of acetic acid. The gelatine

soon disolves, forming a liquid glue which when dry is much more brittle than gelatine.

Acid in any form is therefore undesirable as far as the wearing qualities of film are concerned, but if it is used the concentration should not exceed 0.05% or 1 part of glacial acetic acid to two thousand (3 oz. per 50 gal.) otherwise softening of the gelatine is liable to occur especially if the temperature of the dye-bath exceeds 70 degrees F.

It is common practice in many film laboratories, when the dye bath works slowly to add a further quantity of acetic acid to increase the rate of dyeing. This is done repeatedly until the dye-bath contains practically no dye at all and a strong odor of acetic acid is present in the drying room. Such maltreatment of film is responsible for most of the complaints of brittleness and is to be deplored. The cost of the dye is insignificant as compared with the value of the film treated so that a dye-bath of sufficient strength should be made in the first place and a strong solution of the dye added as required in order to revive the bath. Fifty gallons of dye bath of a concentration of 0.2% will usually tint 40,000 feet of film.

Choice of Colors

Although it is possible to match any tint by suitable admixture of one or more of three colors, magenta, yellow and blue green, when mixing colors in this way the mixing must be done with great precision since a slight variation in the quantity of any one of the ingredients produces a marked effect, so that it is simpler to include intermediate colors, such as orange, green, etc., as standard tints.

Seven standard tints have been chosen: namely, red, scarlet, yellow, light green, green, blue and violet. The problem of matching tints with standards is then a simple matter.

In selecting any particular dye, account has been taken of the purity of its color. Some dyes have a muddy appearance as if a certain amount of black dye had been mixed with it. This has the effect of diminishing the screen brightness so that in order to maintain constant screen intensity more current must be used in the projector. The purity of color of the dyes selected below is sufficient for all practical purposes.

American Film Tinting Dyes

The following American made dyes which fulfill the above conditions as nearly as possible are recommended for film tinting:

TINT	NAME OF DYE	OBTAINED FROM
Cine Red	Amaranth	Calco Chemical Co., N. Y. C.
Cine Scarlet	Crocein Scarlet MOO	Natl. Aniline & Chem. Co., N. Y. C.
Cine Yellow	Quinolin Yellow	Natl. Aniline & Chem. Co., N. Y. C.
Cine Lt. Green	Napthol Green Conc.	White Tar Aniline Corp., 56 Vesey St., N. Y. C.
Cine Green	Acid Green L	Natl. Aniline & Chem. Co., N. Y. C.
	Wool Green B	White Tar Aniline Corp., N. Y. C.
Cine Blue	Direct Blue 5B	Essex Aniline Wks., 39 Oliver St., Boston, Mass.
	Acid Blue GR	Newport Chem. Wks., 120 B'way, N. Y. C.
Cine Violet	Buffalo Fast Violet B.	Natl. Aniline & Chem. Co., N. Y. C.

The above list of dyes has been selected after testing more than five hundred dye samples, but is necessarily incomplete because new dyes have appeared on the market since these tests were made.

The Eastman Kodak Company is anxious to recommend satisfactory tinting dyes so that if manufacturers will submit samples of new dyes to the Research Laboratory, Eastman Kodak Company, Rochester, New York, they will be carefully tested with a view to recommending those suitable for film tinting.

In cases where alternative dyes have been recommended, they may differ slightly in regard to color, rate of bleeding, etc., and are therefore not strictly interchangeable. This is due to different methods of manufacture. In the following formulæ the first dyes indicated on the above list were used.

The strength of the dyes may vary from batch to batch, the same dyes made by different makers differing particularly in this respect, so that when purchasing it is desirable to secure a statement of the percentage of pure dye in the sample. As stated above, a certain percentage of salt or sodium sulphate is present in most commercial dyes, so that when comparing prices the amount of impurity present should be taken into consideration.

Formulae for Tinting at 65° (F).

Tint No.	Dye	Avoirdupois	Metric	Time of Tinting
1	Cine Red	2 lbs.	1000 grams	3 minutes
	Water	50 gals.	200 liters	
2	Cine Red	13 ozs.	400 grams	3 minutes
	Water	50 gals.	200 liters	
3	Cine Scarlet	26 ozs.	800 grams	3 minutes
	Water	50 gals.	200 liters	
4	Cine Scarlet	13 oz.	400 grams	3 minutes
	Water	50 gals.	200 liters	
5	Cine Yellow	18 ozs.	540 grams	3 minutes
	Cine Scarlet	1 oz. 150 grains	40 grams	
	Water	50 gals.	200 liters	
6	Cine Yellow	18 ozs.	540 grams	3 minutes
	Cine Scarlet	1 oz. 150 grains	40 grams	
	Water	50 gals.	200 liters	
7	Cine Yellow	13 ozs.	400 grams	3 minutes
	Water	50 gals.	200 liters	
8	Cine Lt. Green	26 ozs.	800 grams	3 minutes
	Water	50 gals.	200 liters	
9	Cine Green	26 ozs.	800 grams	3 minutes
	Water	50 gals.	200 liters	
10	Cine Blue	13 ozs.	400 grams	3 minutes
	Water	50 gals.	200 liters	
11	Cine Blue	13 ozs.	400 grams	1 minute
	Water	50 gals.	200 liters	
12	Cine Violet	13 ozs.	400 grams	3 minutes
	Water	50 gals.	200 liters	

Method of Preparing the Dye Solution

Dissolve the solid dyes in as small an amount of hot water as possible, and filter through fine muslin. Pour hot water over any residue remaining to insure thorough solution of the dye, and

dilute the solution in the tank to the required volume at 65 degrees (F).

Nature of Positive Film

Only good snappy positive film may be successfully tinted, since tinting tends to reduce contrast.

The depth of the tint obtained depends on the following factors:

1. Nature and Strength of the Dye-Bath

Except in special cases, such as fire scenes, sunset and moonlight effects, it is very undesirable to employ strong tints, since apart from the displeasing effect and irritation to the eye, the dyes produce a slight softening of the gelatine film when used at 80° (F) in a 1% solution.

Should it be necessary to employ concentrated baths in summer, either cool the dye bath or use a suitable hardener. This will be unnecessary if hardener is employed in the fixing bath after development, but otherwise if formalin (40%) be added to the dye-bath to the extent of 1 volume to 400 volumes of dye solution, no trouble will be encountered. During the winter months when it is advisable to treat all film after developing and fixing with glycerine, the latter may be incorporated with the dye bath, thereby eliminating an extra operation. The strength of the glycerine should be 2%, or two volumes per one hundred volumes of dye solution. In most cases, however, the addition of glycerine considerably retards the rate of dyeing and in order to obtain the same degree of tinting in a given time, the concentration of the dye bath should be increased accordingly.

When delicate tints are employed, the effect is both to remove the contrasting black and white effect, and to add a touch of warmth to the black deposit of silver, even in cases where the highlights are insufficiently stained to be noticeable. The result in many cases is equal to that obtained by partial toning.

2. Temperature of the Dye-Bath.

Although temperature has little effect on the rate of dyeing with the dyes recommended, when used without the addition of acid, it is advisable in all cases to work at 65 to 70° F. to produce uniform results and remove any danger of softening the film.

3. Time of Dyeing

In order to duplicate any particular tint with a given dye-bath the film may be dyed either by time or by inspection. Dyeing by time is reliable if the dye-bath does not contain acid, though if acid is present, in time the acidity decreases, causing a slowing down of the rate of dyeing, so that it becomes necessary to judge the progress of dyeing by inspection.

If two or more tints of the same color are required, it is better to vary the time of dyeing rather than to vary the dilution of the bath, as a means of reducing the number of individual dye-baths to

a minimum, providing the time of dyeing for the lighter tint is not less than one minute, which time is considered a minimum for the production of uniform results and for complete control of the dyeing operations.

The time of dyeing also depends somewhat on the previous handling of the film. Film which has been fixed in a bath containing ordinary—or chrome alum, dyes more quickly than that created with plain hypo and hardened with formalin.

It is probable, therefore, that small traces of alum, which serve as a mordant for the dye, are left in the film even after prolonged washing.

Should the film for any reason be over-dyed, a small portion of the dye may be removed by washing for 10 to 15 minutes, though the fastness of the dyes to bleeding will permit only slight mistakes to be rectified in this manner.

Life of the Dye-Bath

This averages about 40,000 feet of film per 50 gallons of dye-bath. As the rate of dyeing slows down the bath should be revived by adding a concentrated solution of the dye and not by adding acid. When the bath becomes muddy, especially in warm weather, it should be renewed.

Method of Procedure

Either the "drum" or the "rack" method may be employed, the rack being agitated slightly to insure even dyeing and prevent accumulation of air bubbles, after which the film should be given a thorough rinsing in plain water.

Before drying films on racks it is advisable to set the rack at a slight angle for a few minutes, to enable the surplus water to drain off more readily through the perforations. If drums are used for drying it is advisable to remove the surplus water by whirling the drum previous to drying.

If uniform results are to be obtained, film should never be passed through the projector before either tinting or toning.

How to Obtain Intermediate Tints

Sample tints may be readily obtained by making a trial with a small amount of solution on a short length of film, taking care to match the tint in artificial light and not by daylight.

When matching think of the tint as being made up of one or more of the colors, red, yellow and blue. Colors such as orange are made by mixing yellow and red, violet by mixing red and blue, and green by mixing yellow and blue. Browns are obtained by mixing all three colors, red, yellow and blue.

Local and Multiple Tinting

Very pleasing effects may be secured by locally tinting a portion of the film picture. This can be done either by coloring each picture separately by hand or by cutting a stencil and applying the dye through the stencil by application rollers or by spraying, or a

resist such as a transparent varnish may be applied either by hand or by stencil to those portions which are not to receive dye and the film immersed in the dye solution in the usual way. Multiple tinting is executed in the same way.

Light Transmission

The amount of light cut off from the screen as a result of tinting depends upon the nature of the particular dye, the concentration of dye in the film, and on the purity of color of the dye. An interesting series of measurements recently made in the Research Laboratory of the Eastman Kodak Company show that the screen brightness is diminished by from 25% to 95% as a result of tinting. Excepting in special cases, therefore, it is very desirable to keep the tints as light as possible or at least no deeper than is required to produce the necessary color sensation.

Troubles in Tinting

Streaks and uneven coloring may be caused by:

(a) Grease on the film. Film should never be projected before being tinted.

(b) Excessive bleeding of the dye, allowing the film to stand too long after rinsing and before placing on the drying rack, or insufficient squeegeeing of the film when placing on the drying rack.

(c) Too low a humidity in the drying room. If the air in the drying room is too dry, while the film stands on the rack previous to placing on the drying reel, the edges of the film commence to dry while the center is still moist with water charged with dye which has bled from the film. Even after squeegeeing under such conditions drying marks will be produced and are apparent on the screen as streaks. The remedy is to keep the relative humidity of the drying room around 60% to 70% and to squeegee the film either by means of a blast of air or by chamois as quickly as possible. All drying rooms should be equipped with a recording hydrometer placed in close proximity to the drying reels.

Precipitation of the Dye

This is usually due to the presence of alum, calcium, magnesium or iron salts in the water supply as described above.

Heating and Ventilation of Motion-Picture Theatres

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The solution of the problem of heating and ventilation in theatres may best be understood by analyzing the requirements involved. Ventilation is of vital importance in all buildings, and especially where a large number of people are assembled; and it has been proven conclusively that mechanical means is the only practical, reliable method. Heating necessarily goes hand in hand with ventilation during several months of the year in most localities.

An average person breathes nearly one-half cubic foot of air per minute; the entering air contains 20.9% or more of oxygen and .04% of carbon dioxide; the respired air contains but 16% of oxygen and 4% of carbon dioxide. The normal amount of carbon dioxide in the atmosphere is 4 to 6 parts in 10,000 and, as the proportion in a given volume of air is easily determined, it is taken as a measure of the purity of the air. Carbon dioxide is not directly harmful in itself, but its abundance shows the extent to which the oxygen of the air has been depleted and the air loaded with harmful organic exhalations.

A small diminution of the percentage of oxygen in air impairs its life-sustaining power, and in fact, every breath of air we take is practically exhausted for breathing purposes when it is exhaled. The air on mountain tops and at the seashore consists of 79.1% by volume of nitrogen and 20.9% of oxygen. When the proportion of oxygen falls to 20.8%, a room feels close; even in mines it is rarely less than 20.4%, and at 18.5% candles go out. At 17.2% it is impossible to remain in the air many minutes. Withdrawing oxygen to the extent of 1-500th part of the volume of air reduces the luminosity of a candle by 1-20th. It can then be appreciated why depleted air results in low mental and physical vitality and that the problem of supplying pure air is, under modern conditions, more important than the supplying of food. The more continuous the exposure to bad air, as in schools or theatres, the more serious are its harmful effects.

The usual ventilating apparatus consists of a centrifugal fan, a battery of steam coils, and an air washer which, in addition to purifying the air, adds moisture which is equally as necessary during the winter months as heat itself. In addition to the above, a system of galvanized steel or concrete ducts is required for the proper distribution of the air to the various portions of the building without the possibility of objectionable drafts. A number of states and communities have passed laws requiring a certain volume of air to be delivered into a building for each occupant, usually requiring 30 cu. ft. of air per person. This, in a measure, determines the size fan for any particular theatre or other public building, it being of marked importance to select a fan capable of delivering this air at a comparatively low outlet velocity to prevent the possibility

of objectionable noise. Theatres should be equipped with sufficient direct radiation to maintain a temperature of 70° F. under extreme weather conditions. This is recommended so the temperature in the theatre may be kept above the freezing point at night after closing hours, without operating the fan apparatus. The steam coils used in connection with the fan should only be sufficient to raise the temperature of the air used for ventilation to a temperature of approximately 75° F. under extreme weather conditions. The air washer must be of sufficient capacity to cleanse thoroughly the air, remove dust, soot and other foreign substances, and at the same time partly saturate the air with moisture at a temperature of approximately 42° F. Sufficient steam coils must be placed at the inlet of air washer to raise the temperature of entering air to about 39° to prevent the temperature in the spray chamber ever dropping below this temperature, and thus eliminating the possibility of the spray chamber freezing up. The air after passing through the washer is drawn through the fan, and is discharged over the steam coils, heating it to the temperature of about 75° F. at which it is delivered into the building. The ducts must be of ample capacity to transmit the air to the various portions of the building at a comparatively low velocity to prevent objectionable drafts and noises.

There are two well-known methods of introducing the air into a theatre; first, the mushroom system, and second, the overhead system. With the mushroom system the air is introduced through a large number of small cast iron ventilators placed underneath the seats, there being a plenum chamber immediately below the floor, usually constructed of concrete. These mushrooms must be sufficient in number to keep the velocity down not to exceed 500 feet per minute, and it usually requires one under every other seat in each row. The peculiar shape of these outlets, which resembles the mushroom, gives the system its name. This system is more expensive to install and can rarely ever be adapted to existing buildings without considerable remodeling, and hence, to be used to advantage, should be specified when the building is erected. The big advantage of this system is, that there is a continuous movement of air from the floor to the ceiling from which it is exhausted outside the building by means of large ventilators or an exhaust fan. This immediately removes all bodily heat and exhalations, and the air in the breathing zone is always pure and fresh.

The second method of introducing the air into a theatre is by far the more common and is readily adaptable to an existing building. By this method the air is introduced through ducts placed in the side walls usually built into hollow pilasters and the outlets are placed about 8 ft. above the floor. These outlets are covered with grills and can be made to harmonize with any existing schemes of interior decorations.

The mushroom system is in my opinion the more desirable. It insures uniform ventilation throughout the building without the possibility of objectionable drafts, while in the case of the over-

head system the air must necessarily be blown in at the side walls at a comparatively high velocity to insure any fresh air reaching the central part of the building. Furthermore, it is blown in 7 or 8 ft. above the floor line and must be directed downward in order to reach the breathing zone, and unless the system is scientifically laid out, a large percentage of this fresh air passes out without serving its purpose and there are apt to be stagnant areas in some parts of the building. With this system the foul air is usually removed through vent registers in the walls at the floor line. From there it passes to the attic through ducts in the walls, and discharged outside the building, usually by an exhaust fan.

One point which is very much overlooked is the importance of positive removal of the foul air as the fresh air is introduced. If it is not promptly removed it will mix with the incoming fresh air and again be thrown into the breathing zone, and in a large theatre an exhaust fan placed on the roof or in the attic is recommended. In smaller theatres natural draft ventilators are used. The gallery is usually taken care of by a separate fan or ventilator placed on the roof.

There is no building which should receive more careful attention with reference to proper heating and ventilation than the theatre. It represents one of the most interesting problems for the heating and ventilating engineer to solve. The immense open area, and the large number of people combine the extremes in both heating and ventilating conditions. The rapidly increasing number of motion-picture theatres has caused the fan engineer to give this subject more consideration than in the past. The majority of the patrons at a theatre attend to be entertained, and if atmospheric conditions aren't such as to insure comfort, the patron is apt to become impatient, dissatisfied, and will seek pleasure elsewhere.

Sufficient air at the proper temperature is not the only essential. Humidity is of equal importance with reference to both comfort and health. By humidity we mean, of course, the amount of moisture in the air.

You must appreciate that dryness of air is a relative thing. It has nothing to do with the amount of moisture actually contained as you might suppose, but it depends upon the temperature of the air, as that temperature is related to the actual moisture contents. Remember the quantity of water vapor which the air can hold depends upon its temperature. As an example of what is meant: Suppose the outside temperature is zero. Even if the air is saturated at zero it can hold but a minute quantity of water vapor (½ grain per cu. ft.). If that same air is taken into a building and heated to 70°, its capacity to hold water vapor is increased 16 times.

The outside air at zero, and the inside air at 70° may both contain the same actual quantity of water vapor, but the outside air was saturated, that is, as wet as it could be, while the heated inside air contains but one-sixteenth of the water vapor which it is capable of holding, therefore the inside air is very dry; thus you

can see that the dryness of air is related to its temperature rather than its actual moisture contents, hence the term "relative humidity" which is expressed in percentage. If we say that the relative humidity is 50%, we mean that at the given temperature the air contains 50%, or one-half as much water vapor as it would contain if it were saturated. The relative humidity, therefore, varies as much with the temperature as with the actual quantity of water vapor mixed with the air.

It is quite generally agreed that humidities below 30 are unnatural and injurious physiologically, and tend to reduce the efficiency of the occupants of the building. This is due, first, to the fact that excessively dry air overworks the mucous membrane of the nose and other air passages, and second, because its effect upon the skin or upon the mucous membrane, has an irritating effect upon the nervous system. This has been the experience and conclusion of a great many observers who have investigated the subject. In addition to the bad effect physically, excessively low humidity is objectionable due to its effect upon the furniture, woodwork, pipe organs, etc., which is well known, but perhaps not properly appreciated.

The effect of low humidities is not so serious except where accompanied by comparatively high temperature, but it is necessary to carry a higher temperature in a building where the humidity is low in order to obtain what we might call the necessary sensible temperature which will be referred to a little later.

Another objection to a high temperature and low humidity in any building is that when a person enters the building his clothes are apt to be filled with moist air due to rain, snow or high outside humidity, and with this great amount of moisture in his clothes, he at once feels damp and cold due to evaporation, a very bad combination, the effect of which need not be commented upon further.

There is a corresponding objection to an excessively high humidity. Humidities above 65% are objectionable when accompanied by a room temperature of 70° or more, due to the pronounced soothing effect to which the nervous system is subjected in contrast to the more or less stimulating effects produced by extremely low humidities. High humidities cause a tendency towards lack of energy and even sluggishness. The effect of excessively high humidities is drowsiness, and patrons are apt to enter dreamland during the most interesting part of a film story.

From the foregoing the need of automatic humidity control to prevent either excessively low humidities or excessively high humidities is evident. The air washer as such produces a considerable degree of humidity for the reason that it partly saturates the air which is passed through it, but of itself it does not control the degree of saturation nor the temperature of saturation. In other words, the humidity may be either too high or too low, probably some of the greatest dangers being that the humidity will be too high; the cost of operating excessive, and the conditions of ventila-

tion unsatisfactory. In addition to excessive humidity, especially in the winter months, being objectionable for physical comfort, it takes a great deal of heat to evaporate a pound of water into a pound of water vapor, even without raising the temperature of the vapor above that of the liquid. As an illustration: If the amount of heat necessary to evaporate one pint of water were converted into work, it would lift a man weighing 150 lbs. from sea level to the top of a mountain 5,000 ft. high.

The peculiar thing about dry air is that it must be heated to a much higher temperature to feel the same degree of comfort. Air at 58° F. is comfortable, provided the relative humidity is at least 65%; while if the air is extremely dry, say 30% humidity, it is necessary to carry a temperature of 75° for the same degree of comfort. The best conditions in a theatre would be a temperature of 70° and about 50% relative humidity. You will remember the fine days in early June when you halted just outside the front door, took a long deep breath and started for the day's work with a smile on your face, a wonderful vigor in your stride, a keen, brilliant light in your eyes, and your mind clear. That's not due to Springtime—it's because the temperature is about 70° and the relative humidity 50%.

During the summer months, of course, the heaters are not in use, but the supply fan continues to deliver its full volume of air into the building, and the air washer continues to remove all traces of dust, soot, etc., from the air and often cools it from 10° to 15° by evaporation. The amount of cooling, of course, depends upon the outside relative humidity. If the air is already nearly saturated, little, if any, cooling is obtained, but if the outside air is comparatively dry, as is the case in many parts of the country, there is a very marked cooling even if the water in the air washer is recirculated, as most of this cooling is obtained by evaporation, rather than from the air coming in contact with water at a lower temperature than air. This is generally referred to as evaporative cooling. As an illustration: Moisten one of your fingers and blow upon it—your finger feels cool. Now blow upon one of your dry fingers and there is a warm feeling. When you blew upon your moist finger your breath immediately began to evaporate the moisture. You will remember I referred above to what an astonishing amount of heat is required to evaporate a pint of water. In the summer when no heat is being applied to the spray of water, the air must give up some of its heat in order to evaporate the water. In other words, dry air, greedy for water vapor, is forced to pay for the water vapor with heat; hence the cooling effect when air is passed through a spray chamber. Needless to say the hotter it is outside, the greater the cooling obtainable inside by means of this evaporation. An installation was recently made in Denver, Colo., where the cooling, due to evaporation, was from 25 to 30 degrees below the outside temperature. This would naturally tend to make a theatre a very popular place during the warm months, and a theatre so equipped is due to

be more attractive than the stuffy ones not equipped with mechanical means of ventilating, heating and cooling.

Taking, as an example, a theatre having a seating capacity of 2,000, we find it necessary to install an equipment having a normal capacity of 60,000 cu. ft. of air per minute. This would require a fan measuring about 10 ft. in height, which could be easily installed in the basement of any modern theatre. The power required for delivering the above volume of air would not exceed 12½ H.P. The air washer should have a clear area of about 120 sq. ft., approximately 10 ft. high, 12 ft. wide, and it would require a centrifugal pump with a 7½ H.P. motor for recirculating this water and delivering it to the spray nozzle at the required pressure. The same water is usually recirculated and only sufficient fresh water added to replace that evaporated by the air.

The tempering coils placed at the inlet of the washer should be capable of heating the air from, say zero to a minimum temperature of 39° F., and would require a total of about 3,000 feet of 1-inch pipe. The total condensation in these coils per hour with an outside temperature of zero would be about 2,500 lbs. of steam. The necessary heat ejected into the water used in the spray nozzles of the air washer would be about 1400 lbs. per hour. This heat would only raise the temperature of the air from 39° to 42° F., about 80% of it being required to evaporate the water used for partially saturating the air. The re-heater coils should increase the temperature of the air from 42° to 75° F., and should contain about 3,400 feet of 1-inch pipe, and the condensation would be about 2,300 lbs. per hour, so the total amount of steam required per hour for a theatre of this size would be approximately 6,250 lbs., corresponding to 180 H.P., but as zero conditions do not exist many days throughout the year, 150 H.P. boiler arranged properly for carrying a slight overload would be of ample capacity.

The centrifugal pump for recirculating the water in the air washer and spray nozzles should handle a total of about 320 gallons per minute against a pressure of approximately 30 lbs. per sq. in.

If an exhaust fan is placed in the attic or on the roof for removing the foul air, it should have a capacity of 45,000 cu. ft. per minute. Since the supply fan delivers 60,000 cu. ft. to the building, it has been found that nearly 25% of this amount escapes by means of leakage around doors, windows, etc., there is a slight pressure in the theatre above the atmospheric pressure. An exhaust fan capable of handling this volume of air would require only 5 H.P. The approximate cost of such a system, consisting of supply fan, tempering coils, air washer, re-heater coils, centrifugal pump and attic exhaust fan, together with necessary motors and galvanized iron distributing pipes and mushroom ventilators, based on the mushroom system, should not exceed $12,000.00. This includes cost of installing the equipment, but does not include the boilers.

At first thought this may appear high considering that direct radiation must be used in addition, but the advantages such an

installation gives a theatre can scarcely be over-estimated. The increased patronage due to favorable climatic or atmospheric conditions will pay for the apparatus many times in a single year, while the life of the equipment is easily a quarter of a century.

The Various Effects of Over-Speeding Projection

By F. H. Richardson

Paper designed to cause discussion—Effect of overspeeding on projection mechanism—Over-speeding has a tendency to aggravate the evil of oil on film—Makes picture unsteady—Has bad effect on film sprocket holes—Alters speed of motion of moving objects in screen picture and injures artistic effect—Affects the music rendition—Has one beneficial effect.

That speed of projection which will produce absolute naturalness of action of moving objects in the screen picture is the speed which will cause precisely the same film footage to pass the projector aperture per minute as was passed over the camera aperture in the taking of the scene being projected. This is, I think not a subject for argument, but merely a statement of known fact.

The Society of Motion-Picture Engineers, has, in its wisdom, seen fit to establish as normal speed of projection, i. e., that speed which will cause sixty feet of film to pass over the projector aperture per minute. This action presumably was founded on the presumption that "taking" (camera) speed would also be at the rate of sixty feet per minute. Presumably it was expected by the society that the projectionist would vary his speed of projection either above or below normal when it became necessary by reason of variation in "taking" (camera) speed to do so in order to produce naturalness of action of various objects in the projected picture.

Personally, the writer may and does disagree with the wisdom of adopting sixty feet as the projection speed standard, believing a somewhat higher rate of speed better calculated to synchronize with modern camera speed, and to avoid the flicker tendency which is present under modern practice which involves high screen brilliancy; but that is beside the point.

This paper is designed to set forth for your consideration those various effects which result from the over-speeding of projection, but let it be clearly understood that insofar as applied to moving objects in the screen picture, over-speeding can only be considered as taking place when projection speed is greater than was the speed of the camera which took the scene; also that the various effects hereinafter described will be of small or great in exact proportion of the variation of projection speed from normal, or, in case of screen action, from camera speed. The paper has, also, as one of its chief objects the stimulation of study and discussion of the whole subject of projection over-speeding and its effects.

Effect on the Projector Mechanism

First let us examine into the effect of over-speeding on the projector mechanism itself. We may fairly assume that the engineers who designed projection mechanisms based their calculations as to the effects of abrasions, strains and stresses that moving

parts would be called upon to withstand, upon what those abrasions, strains and stresses would be at normal speed of projection, with, of course, the usual allowance for occasional temporary overload (excess speed), just as designers of electric generators base their calculations on normal load, with allowance for occasional temporary overload. It is a well-known fact that a properly designed and constructed electric dynamo will give its maximum service at normal full load, and that it will not be appreciably injured by an occasional overload, up to even as much as one hundred per cent, provided such overload does not extend over more than a brief, stated period.

Practically exactly the same thing is true of the projector. Modern projector mechanisms will give astonishingly long, efficient service when used at normal load (which in their case means normal speed) provided there be intelligent care, lubrication and proper adjustment of the tension pressure upon the film at the aperture for that speed. It is also true that the mechanism will not be materially injured, or have its working like appreciably shortened by occasional temporary excess in projection speed, even though the excess be as much as one hundred per cent.

If, however, we place an electric generator under constant heavy overload, or maintain periodic heavy overload for too long periods of time, serious damage will inevitably result, which may and most likely will very greatly shorten the life of the machine as a whole, and most certainly will work serious injury to, or even cause the complete destruction of its vital working parts.

Precisely the same thing is true of the projector. Excessive speed subjects all moving parts thereof, but more particularly the somewhat delicate high-speed parts, to a strain they were never designed or intended to withstand.

We have cited the analogy of the electric generator by reason of the fact that it is one with which we are all, we think, reasonably familiar.

The foregoing is perhaps not sufficiently detailed to be entirely convincing. We will therefore examine into the matter somewhat more minutely. At normal projection speed (sixty feet of film per minute) the projector intermittent movement acts at the rate of sixteen times per second, each time causing the delivery by the actuating cam pin, or diamond, upon the star or cross, what amounts to a sliding hammer blow, of sufficient force to start the intermittent sprocket and shaft revolving, against the inertia of the parts, plus the friction of the bearings and against the inertia of about six inches of film, plus the constantly exerted braking friction of the tension shoes upon the film, all of which is, you will realize, a not inconsiderable force to overcome, even under the very best conditions possible. Yet at normal speed this must be done at the rate of 960 times per minute, and the movement must, after being brought to maximum speed, be again slowed down to an absolute stop an equal number of times.

If we increase the projection speed to one hundred feet of film

per minute this movement is increased to 27.66 per second, or 1,599.6 per minute and if we still further increase projection speed to 120 per minute it reaches the enormous total of thirty-two per second, or 1,920 per minute. Think of it! Thirty-two times per second the intermittent must start its mechanism and several inches of film, against the pull of the various forces before enumerated, from dead still bring the parts to high speed and again stop them to absolute stillness. And this must be done by comparatively light mechanism, which must be, and remain absolutely mechanically true (absolutely) in the ordinary meaning of that term. There is nothing actually "absolutely mechanically true," if it is to give a perfectly steady picture on the screen.

In considering this matter, it is well to remember that the normal speed of a twelve-inch circular saw is less than two thousand revolutions per minute. The speed of the armature of electric generators, except small, high-speed generators, does not nearly reach nineteen hundred per minute. It therefore follows that at a projection speed of 120 per minute the intermittent movement is taking place at a speed greater than the normal speed of a twelve-inch circular saw, or the normal speed of the armature of the electric generator.

It should require no unusual powers of discernment to understand what the ultimate effect of such a terrific strain will be, if long continued. It cannot but result in the very great shortening of the life of the mechanism, and the rapid breaking down of its accuracy of function.

It is quite possible there are those who do not realize the frequency with which over-speeding is practiced in theatres. For their benefit I will say that hundreds upon hundreds of theatres, or so-called theatres at least, make it their regular practice to project a thousand feet of film in as little as eight minutes. Other hundreds do the same thing at certain "rush hours" of the day, either every day or on certain days of the week. Eight minutes to the thousand feet of film is at the rate of one hundred and twenty-five feet per minute. It is a deplorable fact that even some large, otherwise high-class theatres make it their habitual practice to project at the rate of from ninety to a hundred feet per minute.

The resultant damage to film and machinery is directly in proportion to four things, viz.: (A) The amount of excess speed. (B) Amount of braking power the tension shoes exert on the film. (C) Condition of the mechanism and (D) Lubrication of the Mechanism.

It is a well-established fact that the exhibitor who abuses his projectors by over-speeding, almost invariably blames their consequent shortness of life and the excessive repair bills upon faulty construction of the projector itself, instead of upon the abuse to which he has caused it to be subjected.

Oily Film Traceable, in Part, to Over-Speeding

Another evil the motion-picture industry is called upon to bear which, while not entirely due to over-speeding, is nevertheless greatly

augmented thereby, is oil on the films. If we examine the films in any exchange we will be reasonably certain to find seventy-five per cent of them carrying oil to some extent. A goodly share of this percentage will carry considerable oil, while some films will be literally smeared with it.

This state of affairs is traceable to several causes, but it is a condition always greatly aggravated by over-speeding, partly because of the natural inclination to over-oil a mechanism which is working under heavy stress, and partly by reason that as speed of rotation of revolving parts increases there is added tendency to throw off oil by centrifugal force, and much of which finds its way, eventually, to the film.

Unsteadiness of the Picture

Is always greatly aggravated by any considerable excess in projection speed above normal. This is due to several causes. First, there is the rapid wear of mechanism parts, which very naturally makes for lost motion and unsteadiness of the picture. Second, there is increased tendency to wear off intermittent sprocket teeth, due to added strain of excessively tight tension required for high speed, and worn intermittent sprocket teeth always make for unsteadiness in the picture. Third, there is the added tendency to jump when a badly made splice hits the upper end of the tension shoes. In addition to this there is, to some extent, additional vibration of the machine as a whole, which of course to some extent make for unsteadiness of the picture on the screen.

I feel there is no need to further elaborate on this phase of the subject. It should, it seems to me, require no argument to convince even the most skeptical that excess in projection speed makes for unsteadiness of the picture on the screen, nor can the fact that it is possible to project a steady picture at high speed be accepted as proof or even as evidence to the contrary.

Effect of Over-Speeding Upon the Film

One of the important functions of the projectionist is to see to it that the tension springs exert just sufficient pressure upon the film to accomplish the purpose for which they are intended. But the amount of pressure (tension) necessary to stop the film after the intermittent sprocket has ceased to act and to hold the parts in retard, will depend in large degree upon the speed of projection, since the braking action of tension shoes upon the film has entirely to do with overcoming the momentum of the film and holding the intermittent sprocket in retard when the movement ceases to function. It therefore follows that decidedly less tension will be required at normal speed than at high speed, and that, always assuming the tension to be adjusted to the actual requirement, the strain upon the film sprocket holes, the teeth of the intermittent sprocket and the whole intermittent movement as well as the various gears of the mechanism will be greatly increased by increased speed of projection; also that the added tension made necessary by increased projection speed will produce abnormal wear upon the aperture plate tracks, as well as aggragate any tendency of emul-

sion to deposit upon the tension shoes, and to increase the tendency of such deposit to do serious damage to the film.

In connection with the foregoing we must call attention to the fact that by proper construction it is possible to so support the film in its path between the upper end of the film gate and the intermittent sprocket that the film itself will in some measure act to reduce the amount of tension necessary; also that closeness of intermittent sprocket to aperture, and the holding of the film in firm contact with the intermittent sprocket has some bearing on the amount of aperture tension necessary for a given speed.

Before closing this phase of the subject let me cite, in proof of the strain under which the intermittent mechanism of a projector and the edges of film sprocket holes work, the following facts.

So great is the pull of the film upon the intermittent sprocket teeth that even though the teeth be of the finest grade of steel and hardened as much as possible, still the film cuts or wears away the metal in a comparatively short time. In considering this fact as applied to the total amount of pull exerted upon the film, as against its almost negligible inertia plus the braking power exerted by the tension springs, let it be remembered that there are eight of the intermittent sprocket teeth contacting with sprocket hole edges at all times. I think you will agree with me that when the pull is so great that glass-hard steel is cut away from eight teeth at the same time, and the cutting is done by a celluloid sprocket hole edge six one-thousandths of an inch in thickness, and that those sprocket hole edges are contained in a film having considerable money value, the reducing of the pull on the intermittent sprocket-teeth to its lowest possible value is an important item, while increasing it needlessly is a very serious matter indeed; that over-speeding does increase it, always presuming to be reduced to its necessary value for normal speed, cannot, I think, be seriously questioned, though, as before remarked, there may be a less percentage of increased tension pressure for a given increase in projection speed in a mechanism in which the film is well supported in its passage through the film gate, and where the distance from intermittent sprocket to aperture is short. Such claim is made, and it seems reasonable, though the author has made no actual test of the matter.

Summed down, we find that with normal projection speed as against over-speeded projection, there is decidedly less wear of the projection mechanism, intermittent sprocket teeth, film sprocket hole edges, aperture plate tracks, and tension shoes, as well as less tendency for deposit of emulsion on the tension shoes, and less liability of such deposit to do serious damage to the film. We find, also that wear of intermittent movement, gears, bearings and intermittent sprocket holes and sprocket hole edges increases very rapidly with increase in projection speed, as also does tendency to over-oil and the throwing off of oil from moving parts.

Just what the actual damage due to over-speeding projection as expressed in dollars and cents, it is impossible to say, for the reason that no reliable figures are available as to the actual number of feet of film in daily use, the average value per reel of the film in daily use, or the average percentage of damage done to each reel. The writer has himself placed the probable number of reels in daily use in the United States and Canada at 120,000, but the actual figure may be either more or less. From long and intimate association with matters pertaining to projection we believe we are able to form what may be termed a reasonably intelligent idea of such matters. If we accept the number of photoplay theatres in the United States and Canada (16,000) as approximately correct, and assume the average daily program to consist of seven reels, we then have a total of 112,000 reels of film in daily use. If we then, taking new and old together, estimate the average money value of these reels of film at $50.00 cash we will have a total of $5,600,000 as the cash valuation of film in daily use in theatres of the United States and Canada. These figures, while admittedly somewhat in the nature of a guess, will, we believe, err, if at all on the side of conservatism. However, in order to be entirely safe, let us arbitarily subtract from the total the sum of $2,000,000 leaving $3,600,000 as the actual cash value. With these figures before us it requires but a glance to see that, even with the above ultra-conservative estimate of valuation, any considerable percentage of unnecessary damage to film is a very serious matter indeed. Even so infinitesimal an amount (in percentage) as one-tenth of one per cent. of unnecessary damage would reach the respectable sum of $3,600. The personal opinion of the author is that unnecessary damage to film traceable wholly to overspeeding will reach the least one-fourth of one per cent per day, and one-fourth of one per cent is, based on the above estimate of valuation, $9,000. Bear in mind the fact that any damage done to film or to machinery must inevitably be absorbed in the "overhead" of the industry, and that part having to do with film ultimately be charged back to the exhibitor in the form of increased film rental, because in the last analysis every item of expense incurred by the industry, no matter what its form, must be paid for out of box-office receipts, since the industry has no other source of income. Please understand that in the foregoing estimate of probable damage we firmly believe ourselves to have been ultra-conservative—that the actual figure is very much in excess of that named.

In addition to the foregoing we must not overlook the fact that there are not less than 25,000 projectors (probably a substantially larger number) in use in theatres of the United States and Canada. These machines probably cost exhibitors an average of not less than $400 each, or a total of $10,000,000, and if their average life be shortened through abuse in over-speeding by as much as ten per cent., it will be seen that additional serious overhead expense is incurred by the industry, since 10% of $10,000,000 is $1,000,000.

It will, of course, be understood that the values quoted are arbitrary. They are based merely on what the writer believes to be

probable after many years devoted to the study of projection practice. The actual amount of damage may be either more or less. But that damage of considerable amount results to both film and projection machinery through over-speeding will be generally admitted by every one in the least conversant with projection practice I have no doubt. The main intent of this paper is to call attention to the matter in a way which will cause further investigation, rather than to quote exact values of damage actually done to film and machinery.

What Happens to the Music

Another effect of over-speeding projection is to speed up the music, and thus very often ruin its artistic effect. This, however, acts, both ways, because as a matter of fact, unless there be very careful selection of music which will synchronize with projection, it may be found that the projection of some scenes at normal speed will act to slow down the music and thus injure, if not ruin its effect. In the foregoing we assume that there is a certain definite relation between tempo of music rendition and tempo of screen action, and that in most instances the two must agree unless one or the other is to suffer.

Injury to Screen Action

But, after all, by far the greater damage due to over-speeding projection is found in the injury to the action of the photoplay itself. This one thing has, we venture the assertion, done more to render difficult the popularization of the photoplay as a high class form of theatrical entertainment than any or all other causes combined. It has tended to cheapen the photoplay and to prevent its drawing at high prices, except where some story of extraordinary power, supplemented by wonderful scenic effects, has offset the unnaturalness caused by high speed, or where the screen has been supplemented by added attraction.

The industry pays literally high sums to individuals to enact the principal roles in photodrama. This is by reason of the fact that these "stars" have established a "drawing power." In examining into what constitutes this drawing power we are certainly justified in assuming its main foundation to the ability to portray the character artistically. Who will dispute this? And if that be the fact, then does it not follow that their rendition could hardly be improved upon by so ordinary a person as a theatre manager or a projectionist, or even by the producer himself? That much is hardly subject to argument. It may be accepted as fact; and if it is fact, then it naturally follows that the artistic rendition for which huge sums were paid to the artist may only be reproduced on the screen when projection is at precisely the speed at which the camera "took" each individual scene. That, too, is fact, is it not? If the tempo of projection be speeded in any degree above speed of "taking," the effect, insofar as relates to moving objects on the screen, is altered, and the alteration is in exact proportion to the excess of projection speed over "taking" speed.

If the actor enacted a death-bed scene artistically, which was

photographed at sixty per minute, and same scene be projected at ninety, the action of the artist is changed into quick, jerky movements, which convey to the audience an entirely different impression than would have been conveyed had the scene been projected at taking speed. The death-bed scene is still a death-bed scene, true, but into it has been injected an element of the ludicrous, which has the effect of intermixing its solemnity with farce comedy. "Pep" is all very well and highly commendable in its place, but, when pall-bearers are made to come out of the house at something between a trot and a lock-step gallop and to dump the coffin into the hearse with a zip, we believe the "pep" thus displayed is misplaced. Certainly the screen gains nothing by such an absurd speeding up of its action.

It must be noted, however, that there are occasional exceptions where a scene may actually be improved by moderate over-speeding of projection. Such scenes are, however, rare. As a rule they are those where speeding automobiles are involved, with no animate figures other than those in the machines. Such scenes merely form the exception which proves the rule.

In over-speeded projection the film story may carry itself, but it is nevertheless an unnatural, weird and ofttimes entirely absurd performance, which is anything else under Heaven than satisfactory. It gives the effect of unrealness, thus keeping constantly in the subconscious mind of the audience the thought that it is looking at a mere picture, whereas with action at normal speed, with attendant naturalness, it is not at all unusual for the audience to become sufficiently lost in the action to forget the screen and actually live in and with the play.

The author ventures the assertion that over-speeding of projection, as applied to its effect in the alteration of action of moving things on the screen, with resultant effects on the minds of photoplay theatre patrons, is the one worst enemy with which the industry has to contend.

It is not within the province of this paper, which is already too long, though there is ample material for many more pages, to enter into detail as to the causes of over-speeding. They are many, but chief among them is the desire of theatre managers to "run to schedule," which means the allotting to each show a certain number of minutes, regardless of variation in film footage or musical or vaudeville numbers, and the desire to crowd into those minutes a program which can not be properly handled in the allotted time. The average theatre manager seems to consider a reel of film as standing for a certain number of minutes of show. This would be entirely true if

(a) All reels of film had the same footage, and
(b) All cameramen photographed all scenes at precisely the same length;

but films vary widely as to footage, while camera speed is almost anything else but standard. That is cold fact, and never will the screen come fully into its own until it is so recognized and pro-

jection placed in the hands of capable men who can and will compensate for difference in camera speed often as between adjoining scenes, thus producing complete naturalness of action on the screen, or until camera speed be absolutely set at one unalterable standard of footage per minute. This latter is, however, not likely to become an actuality by reason of wide variation of light strength encountered by cameramen, particularly when out on "location."

The One Single Beneficial Effect of Over-Speeding

Is found in the fact that it tends to reduce or eliminate any flicker tendency there may be at normal speed.

The Eccentric Star Intermittent Movement

By Willard B. Cook

The primary mechanical essential for motion-picture projection is a suitable means for advancing the film, picture by picture, between the intervals that successive pictures remain stationary for the purpose of registering their image upon the screen.

To produce the intermittent movement of the film, hundreds if not thousands of mechanical movements have been invented or applied.

Among the earlier successful forms of the intermittent movement were the beater, which consisted of a roller on a crank. This operated in the lower loop between the aperture and the take-up sprocket. During the working portion of its stroke, this roller exerted sufficient pressure on the lower loop to pull down one picture length past the aperture, where it remained stationary until the next revolution of the roller, the objections were its noise and injury to the film.

The harmonic cam, actuating a claw which engaged the perforations of the film, was applied by Lumiere and with slight modifications is used extensively in cameras today although for projectors its use has been nearly abandoned. It has two disadvantages, slow speed and concentration of wear upon a few perforations, instead of distribution over a number of them.

For some years the Maltese Cross, or, as it is better known, the Geneva Star and Cam intermittent movement has enjoyed great popularity and is used by most of the leading projector manufacturers today.

In its best known form it is shown in Fig. 1.

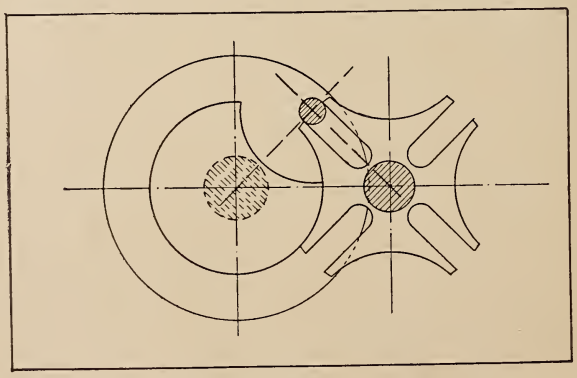


Fig. 1.

It is quite evident that during each continuous revolution of the cam pin, the star will be rotated one-quarter of a revolution. Also that this intermittent movement of the star will occur during only one-quarter of the revolution of the cam and that the star will

remain stationary during the other three-quarters of the cam revolution. This is called a 90-degree cam action.

Place a sprocket on the shaft of the star, with a diameter and teeth to fit four successive pictures to its circumference and you have the common "three-to-one" projector intermittent movement.

As the movement of the film must be masked by the shutter, it is evident that, if the film could be moved more quickly, its stationary image could be correspondingly prolonged on the screen, thus increasing the proportion of the illumination and enhancing the realism of the picture.

Obviously, this can be accomplished by increasing the diameter of the cam and thus decreasing the number of degrees during which the pin is turning the star.

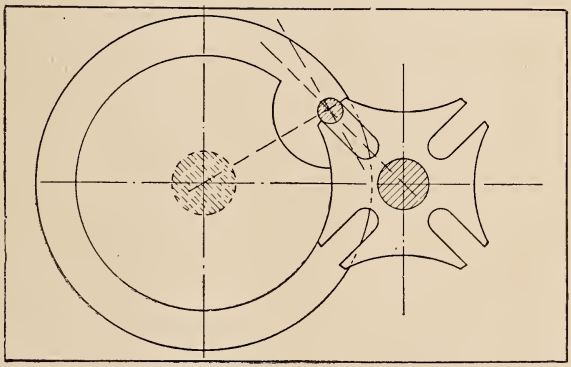


Fig. 2.

This is shown in Fig. 2 which illustrates one form of a "five-to-one" intermittent movement with a 60° cam action.

But note that the pin no longer enters the star slot on a tangent to its travel. Instead, it strikes the side of the slot violently, at an angle of about 15°, which starts the star (and with it the sprocket and film) with a jerk, destructive alike to the mechanism of the machine and the perforations of the film. Such an intermittent movement is subject to rapid wear, besides wearing out the film quickly.

Now, suppose that instead of making the slots in the star radial, they be inclined obliquely in such a manner that the axis of the slot coincides with the tangent to the course of the cam pin at the instant of its entrance.

Fig. 3 illustrates such an eccentric star intermittent movement having a cam action of 60°, or another form of a "five-to-one" movement.

This movement, like the ordinary Geneva Movement, with radial slots shown in Fig. 1, starts the film slowly, without shock or strain on either the mechanism or the film perforations.

But in other characteristics the two movements are surprisingly different, and the eccentric star develops a number of marked projection advantages.

First: On account of the obliquity of the slot, the film starts

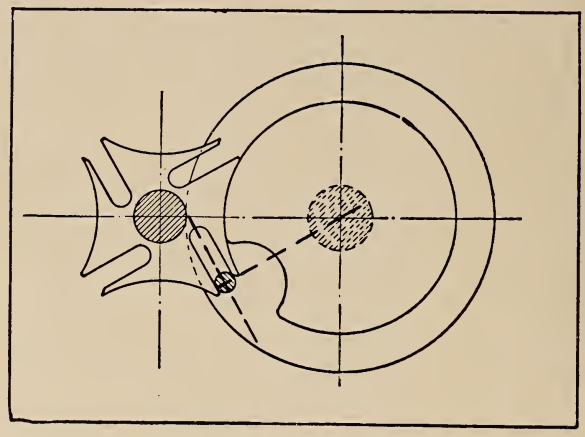


Fig. 3.

more slowly than with the radial slot and its early acceleration of velocity is less. This is of great importance in prolonging the life of the film as the strain on the perforations is greatest in starting the film from a period of rest.

Second: The period of acceleration is prolonged to beyond the middle of the movement. At the middle of the cam action the film has been advanced only one-third of a picture length.

Third: The prolongation of the period of acceleration is accompanied by a corresponding shortening of the period of retardation. This is of advantage in that the friction of the pressure plate or tension springs in the film gate naturally assists the intermittent sprocket to bring the film to a full stop.

It must now be evident to the observer that whereas other rapid intermittent movements wear out both themselves and the film, the eccentric star intermittent movement conserves the life of the film even beyond that of the slower radial star intermittent movement of 90° cam action. Actual life tests confirm this theoretical analysis.

Fourth: It has long been an accepted principle that, with any ordinary intermittent movement, the interrupting or "travel" blade of the shutter must have approximately the same angular area as the action of the cam, plus the additional area necessary to cover the light ray completely before and after the actual movement of

the film. A few degrees on each edge of the shutter blade can usually be trimmed off, because the persistence of vision of the human eye is so poor that the travel ghost due to the slow movement of the film during the beginning and the end of the period of film travel can not be detected.

Thus with a three-to-one intermittent movement a travel blade of 85° to 90° is usually furnished. By the same rule the five-to-one intermittent movement of symmetrical action, like Fig. 2, requires a travel blade of about 60°.

But with the five-to-one eccentric star intermittent movement, as illustrated in Fig. 3, the movement of the film is so slow during the first part of the period of the film travel that it is not perceptible to the human eye and about 15° can be trimmed from the leading edge of the travel blade of the shutter, thus permitting a 45° travel blade without perceptible travel ghost at normal projection speed.

It thus becomes obvious that this movement permits the use of the long desired ideal shutter of minimum flicker, viz.: that of three equal area blades (45° each) separated by three equal openings (75° each). In other words, 62½ per cent of the light from the objective is transmitted to the screen, without the flicker inseparable from the use of any shutter with unequal blades.

Briefly summarizing, the eccentric star intermittent movement makes possible for the first time:

(a) Rapid movement without injury to the film.
(b) Greatly increased illumination.
(c) A 45° balanced shutter, eliminating all flicker.

Standards in Theatre Design to Safeguard from Fire and Panic

By William T. Braun, *Architect*

The adoption of standards in the design of theatres, to safeguard the public from fire and panic, is a subject which is worthy of consideration by a society interested in standardizing the various parts of the industry.

The design from an esthetic standpoint varies considerably with the size of the house, location, amount of money to be spent, the architect's ability, the owner's ideas, etc. Therefore, this paper will not discuss this phase of the subject. There are, however, many points in the design and construction of theatres that should and can easily be standardized for the safety of the theatre-going public. This and the following reasons have prompted the preparation of this paper.

After every great theatre fire in which there has been a great loss of life, there is considerable agitation on the part of officials and the public in general, to try to prevent a repetition of the disaster. The usual result is the drawing of more stringent building ordinances and restrictions, but the general public soon forgets, inspectors become lax, and the laws are not enforced. Although there have been no great theatre fires within the last few years, constant vigilance and agitation by officials and those in a position to suggest will lessen the chances of a holocaust. Also in the smaller cities and towns which at present time support large theatres, there is an absence of carefully drawn building ordinances regulating theatre construction in so far as the safety of the audience is concerned. In fact, in many fairly large cities, there are no regulations whatever, concerning even the most important safeguards. The safety of the patrons is then in the hands of the architect and owner. The architect may not be sufficiently familiar with the many details of this specialized form of building and their great importance, or the owner may, in his desire to cut the cost of the building or to increase the seating capacity, overcome the objections of his architect, endangering the safety of the public. Again, in some towns, there still exist many ordinances that were drafted when the actual dangers of the cinematograph were greatly magnified by men who had little knowledge of the actual conditions. The ever-increasing popularity of the theatre must not be allowed to suffer from accidents due to improper construction or regulation thereof, and the Society of Motion Picture Engineers would do well to recommend these or other similar standards to safeguard the industry where no local regulations exist.

Before discussing these standards let us briefly review, in a general way, how the loss of life usually comes about in a theatre fire and what means and safeguards should be employed to insure the safety of the audience. By so doing, we can tell why the requirements enumerated below should be rigidly adhered to.

In the hundred years (1797-1897) at least 9,355 persons lost

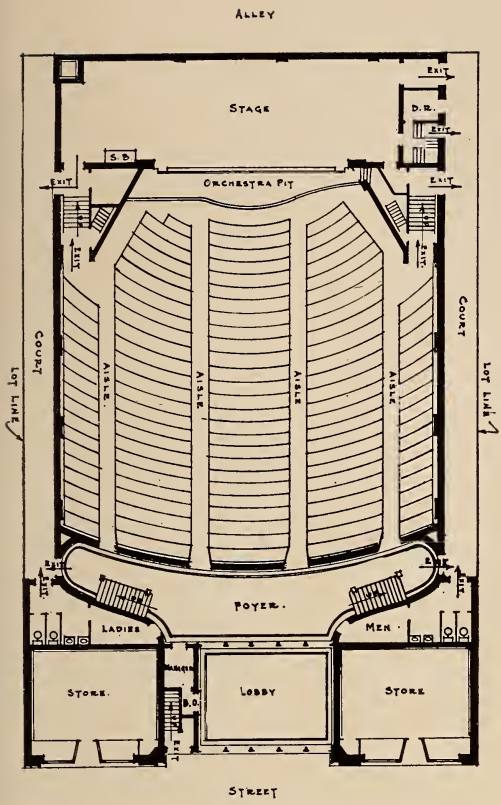


FIGURE 1

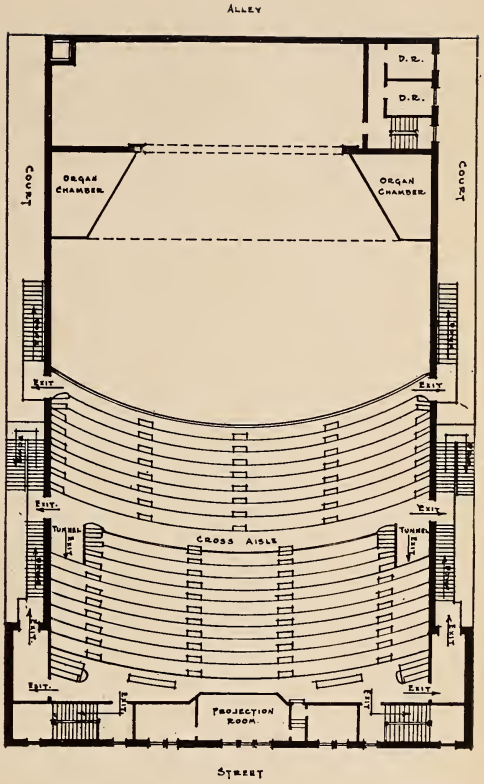


FIGURE 2

their lives in theatre fires, according to William Paul Gerhard in his book on "Safety from Fire and Panic in Theatres." About 14 per cent of these fires broke out while an audience was in the building. In the greater number of fires the loss of life has resulted from the rapid spread of flame on a stage covered with scenery, followed within two or three minutes by an outpouring of suffocating smoke through the proscenium arch into the top of the auditorium, before those in the balconies and galleries could escape. In this way many people in the galleries lost their lives by burning, suffocation due to heat, smoke, fire gases, by shock or fright, and by the crush or jam of the panic in which many were trampled to death; most of this happening within five minutes of the first flame.

In the few fires which have occurred in theatres without a stage and used for the presentation of motion pictures only, the loss of life has occurred by the burning film instead of stage scenery, but the fear and results of panic are the same in any public gathering.

Therefore, the chief considerations for safety of the audience are: Removal of smoke and fire gases accomplished by the quick

opening of ample automatic smoke vents on the stage or in the projection room; the equipment of the stage and other hazardous rooms with automatic sprinklers to smother the flame; the confining of the fire to the stage by means of a fire-resisting curtain at the proscenium opening or the closing of portholes of the projection room by fire shutters, sufficient light supplied by emergency controlled lights, as darkness leads to confusion, struggle, etc.; ample exits, stairways and passages to the main floor and exterior courts, to permit of quick escape of the audience; and fireproof construction to retard the progress of fire.

In the preparation of this paper, the ordinances regulating the construction of theatres in Boston, Chicago, Los Angeles, New Orleans, New York, Philadelphia, San Francisco, Seattle and St. Louis were reviewed and tabulated, as well as the recommendations of the National Board of Fire Underwriters. The standards recommended in this paper are a conclusion or summary of these regulations and are presented in section form, each part of the building covered in a separate section.

As the great majority of theatres now being built are of a larger seating capacity than 300 and most of them have a stage, it will be advisable to limit our discussion to this type. However, in Chicago and in some other cities, there is a special class for theatres over 300, but less than 1,000 seating capacity for the exhibition of moving pictures only, no stage being permitted, and for this type the standards recommended for the balance of the building should be strictly followed.

Section 1. Buildings Included

Every theatre or other building used for the presentation of motion pictures, theatricals or for public entertainment of any kind and accommodating more than 300 persons shall be built to comply with the following sections. These requirements shall apply to every building hereafter erected and to any building remodeled for the above purpose and shall govern the planning and construction whether a stage is provided for or not.

Section 2. Frontages

Every building covered by the above shall have frontage at least on one street. Where the building is not on a corner lot it shall have an open court or passageway on each side of the auditorium extending from the proscenium wall to the street in front. Or, in case there is a street or alley at the rear of the stage, such passage may extend from the foyer to such street or alley. (See Fig. 1) Where a building is on a corner lot and one side of the auditorium fronts on the street or an alley, the passage may be omitted on this side. In a building used for the presentation of motion pictures only, having no stage and all seats are on the main floor, it will be permissible to omit the courts or passage on the sides of the auditorium, provided that there is no cross aisle and there are not more than twenty-five rows of seats and that direct exits shall be provided at both ends of each aisle of such capacity as provided in Section 10, and leading

into street at front and street or alley in the rear. Courts or passages shall be of width provided in Section 11.

SECTION 3. CONSTRUCTION

All buildings of this class and buildings built in connection shall be of fireproof construction throughout, except as follows: Steel of the gridiron shall not be fireproofed. Roof trusses of steel need not be fireproofed unless there is a building over the auditorium, but they shall have a suspended ceiling of metal lath and plaster under them. The steel supporting removable floor traps in the stage floor need not be fireproofed.

SECTION 4. BUILDINGS IN CONNECTION.

Any building built in connection with the theatre shall be of fireproof construction throughout. The building shall be separated from every part of the theatre with a solid masonry wall of thickness required for the main walls of the building. Any part of the building over the auditorium or entrances shall be separated by a fireproof floor. No structure of any kind shall be permitted over the stage. If the theatre is used for presentation of pictures only and there is no stage and all seats are on the main floor and no part of connecting building is over three stories in height, such connecting building may be of ordinary construction, providing it is separated from the theatre as above specified. Buildings in connection with the theatre shall not be used for factory, warehouse, lodging house or for any hazardous purpose.

SECTION 5. SEPARATION OF AUDITORIUM

There shall be a fireproof wall between the auditorium and the foyer, lobby, corridor or any room forming part of the theatre in each tier. Openings shall be permitted only at the end of aisles and shall be protected with self-closing fireproof doors. This shall not apply to motion-picture houses only, as covered in Section 2. The capacity of all foyers, lobbies or passages shall be equal to 1½ sq. ft. for each person accommodated on that tier.

SECTION 6. FLOORS

The auditorium and balcony floors, as well as the floors of all foyers, lobbies and corridors, shall be designed to carry a live load of 100 lbs. per sq. ft. Floors may be either of concrete or other incombustible material or of wood on sleepers imbedded in concrete. Floors at exits shall be level and flush with adjacent inside floors and shall extend for an unbroken width of not less than four feet in front of each exit.

SECTION 7. SEATS

Seats shall be placed not closer than 32 inches back to back. Seats shall be firmly secured to the floor. There shall not be more than six seats between any seat and an aisle.

SECTION 8. AISLES

Aisles with seats on both sides shall not be less than 34 inches wide at the proscenium end, those with seats on one side only 30

inches at proscenium end and all aisles shall increase in width one inch per five feet toward the exits. Unless direct exits are provided at the end of each aisle on the main floor, there shall be a cross aisle every fifteen rows connecting to a direct exit, leading to the outside court or passage. There shall be a direct exit by tunnels or a cross aisle leading to tunnels and emergency exits every 12 feet in the height of the balcony. (See Fig. 2) Platforms in the balcony shall not be higher than 21 inches and shall have a minimum width of 32 inches. When the rise of seat platform is less than 4 inches per foot, floor of aisle shall be made as a gradient. When steps are used in the aisles, risers shall not be more than 8 inches high and treads not less than 10 inches wide. The width of tunnels in the balcony shall be equal to 20 inches per 100 seating capacity that they control but they shall not be less in width than the aisle leading to them nor less than 4 feet wide.

Section 9. Entrances

The width of the main entrance doors and the lobby shall be based on 20 inches for each 100 seats provided. No entrance shall be less than 15 feet wide. There shall be a separate entrance from the street for each gallery or balcony over the first balcony. The floor at the main entrance shall be at the sidewalk level. No auditorium shall have the highest part of its main floor more than 3 feet above the level of the sidewalk at the entrance. All doors in the entrances shall open out in a recess in the wall so as not to block the passage when open, and no doorway shall be less than 5 feet wide. There shall be at least two entrances or exits to every tier accommodating 300 or less, and at least three entrances to every tier between 300 and 500. Over 500 capacity there shall be added 20 inches for each additional 100 seats, to the total width of entrance. All passages or corridors throughout the interior shall be made 20 inches in width for each 100 persons, but they shall have a minimum width of 4 feet.

Section 10. Emergency Exits

Emergency exits shall be provided of the same capacity as the entrances to each tier, opening into the alley at the rear or courts at side. There shall be at least two such exits for each tier on each side of the auditorium and shall be preferably at the top and bottom level of such tier. (See Fig. 2) No such exit shall be less than 4 feet wide. Doors shall open out in a recess in the wall same as for entrances and shall be provided with panic exit bolts arranged to open by pressure against them.

Section 11. Passages or Courts

There shall be provided as in Section 2, courts on each side open to the sky of the following widths: 6 ft. wide up to 600 capacity; 8 ft. from 600 to 1,000; 9 ft. from 1,000 to 1,500; and 10 ft. wide over 1,500 total capacity of the theatre. These passages shall continue either to the street or thoroughfare in front or in back of the building and shall not be closed by any locked gate or doorway. If

it is necessary to pass through any section of the building, a corridor may be used having brick enclosing walls, and fireproof ceiling. The width of corridor shall be the same as that of passage and height shall not be less than 8 feet. The slope of the floor of such passages will not be greater than one foot in twelve feet, except an incline not less than ten ft. long may have a slope of two ft. in twelve ft. to reach the sidewalk or alley level. No steps will be permitted in the floor of such court.

Section 12. Fire Escapes

The emergency exits of each tier shall be connected by exterior balconies and stairs leading from such exits to the passage level. (See Fig. 2) They shall be of steel construction built to carry a live load of 100 pounds per sq. ft. They shall be covered with a hood of sheet metal or enclosed when passing over an exit below. If the flight nearest the court level is counterbalanced, it shall be lowered during the performance. Outside balconies shall be as wide as the exit doorways fronting on them. The width of stairways shall be equal to ten inches for each 100 persons that they may serve, but no stairway shall be less than 3 feet 8 inches wide, and steps shall have a rise of not more than 8½ inches and a tread not less than 9½ inches. There shall be no openings in the theatre wall between the outside balconies and stairways and their covers except the required exits and no person of the audience shall be obliged to pass more than one exit doorway after reaching an outside balcony to get to the ground. (See Fig. 2) Each tier of dressing rooms shall be connected by an exterior balcony and stairway to the ground level. Such stair and balcony shall be of same construction as above, but may be three feet wide.

Section 13. Stairs

All interior stairs shall be constructed of incombustible materials and designed to carry a live load of 100 lbs. per sq. ft. No winders shall be permitted. There shall be at least one or more separate and distinct stairways for each balcony and two for each gallery to the sidewalk level. The gallery stairs shall extend to the top level and shall have exits leading to it from each tier of that gallery. Such stairs shall rise from the entrance lobby or vestibule inside the building and the bottom run of such stair shall lead toward the street and the last riser shall not be further than 60 feet from such street. (See Fig. 1) No flight of stairs shall have less than three risers nor more than fifteen between landings. On stairs which return on themselves the landing be the full width of both flights with corners curved not less than two feet radius. Stairs with a right-angle turn shall have a landing the full width of the flight. Risers shall not be more than 7½ inches high and treads not less than 10 inches wide. The width of stairs shall be based on 20 inches per 100 persons served, but no stair shall be less than 4 ft. 6 in. wide. There shall be a handrail on both sides of stairs placed about 3 ft. above the steps and 3 in. from wall and on flights over 8 ft. wide there shall be a double handrail down the center of such flight with double newels 5 ft. high at ends. The stairs to the

top gallery shall be entirely enclosed but the stairway to the balcony may be open on one side. Stairways on the stage leading to dressing rooms shall be not less than 3 ft. wide. There shall be at least one stairway separated from the stage by a masonry wall leading from each tier of dressing rooms direct to the vestibuled entry of the stage. There shall be a stair to gridiron continuing to roof of stage. Such stair may be circular and may be thirty inches wide.

SECTION 14. STAGE WALLS AND CURTAIN

There shall be a solid masonry wall of the same thickness as the main wall of the building separating the stage portion from the auditorium. This wall shall extend at least 4 feet above the stage roof or the auditorium roof if the latter is higher. The proscenium opening shall be covered with a curtain of asbestos, or steel and asbestos, or other fireproof construction. It shall lap at least one foot on each side of the opening and two feet at the top and shall slide at least 6 inches in metal grooves fastened to the brick wall. The curtain shall be in constant use as the regular curtain and act drop. There shall be but four other openings in the proscenium wall, two on the stage level and two below. These openings shall be no greater than 21 sq. ft. each and shall be protected with automatic fire doors. Other openings in the stage walls shall be protected with fire doors or wire glass windows, in metal frames. No iron guards shall be placed on these windows. There shall be least two exits not less than 4 ft. wide on the stage level one on either side of the stage leading to the outside. These must be vestibuled. (See Fig. 1) Every building used for the presentation of motion pictures only as specified in Section 2, shall not have a stage or proscenium opening. The screen for the picture shall be placed not further than 6 inches from the rear wall of the theatre and a platform not exceeding 80 sq. ft. may be placed in front of it. No rooms of any kind shall be placed between the auditorium and the rear wall of the building.

SECTION 15. DRESSING ROOMS

Dressing rooms shall not be placed on or under the stage or in or under the auditorium. The dressing room section shall be separated from the stage or auditorium by a masonry wall at least 8 inches thick and all openings to the stage shall be protected with self-closing fire doors. All partitions, doors and fittings of every description shall be of incombustible material. All dressing rooms shall be ventilated by fire windows to street or court not less than 24 sq. ft. in area.

SECTION 16. STAGE VENTILATORS.

Over the stage there shall be one or more ventilators built of incombustible material having a free opening and sectional area of at least 10 per cent of the area of the stage. This ventilator shall have either a damper or sliding or hinged sash arranged to open in case of fire. The construction of the damper and the operating mechanism shall be massive and the damper or sash shall open by force of gravity sufficient to effectively overcome the effects of

neglect, rust, dirt, frost, snow or expansion by heat or warping of framework. If glass is used it shall be protected against falling on the stage by a wire screen so arranged that if clogged the effective area will not be reduced or the operating mechanism interfered with. Automatic fusible links shall be used to open the damper or sash in case of fire in addition to manual control provided by a cord run to point on the stage designated by the superintendent.

Section 17. Protection of Stage

There shall be a standard wet pipe system of automatic sprinklers controlling the entire theatre except the auditorium, lobbies and foyers. Sprinkler openings shall be placed around the proscenium opening in back of the curtain so as to form a water curtain when they are opened. There shall be a standard system of standpipes with two 2½-inch diameter outlets at each level of the auditorium and at stage level. Also one outlet at each dressing-room level and gridiron. Each outlet shall be provided with a sufficient length of 1½-inch hose so as to reach all parts of the tier which it controls. There shall be a full equipment of axes, hooks, chemical fire extinguishers and water barrels placed in various parts of the stage to combat the spread of fire. All stage scenery, curtains and decorations made of combustible material shall be painted with a non-combustible material.

Section 18. Lighting

Electric light only shall be permitted on the auditorium and stage portions except that gas light may be used to indicate exits. If exits are indicated by electric light, this service shall have a separate control and be connected ahead of the main service.

Section 19. Boiler Rooms and Carpenter Shop.

Boiler rooms, carpenter or scenery painting shops shall be separated from the auditorium and stage by a fireproof floor or masonry wall or both, and have automatic fire doors in the connecting openings.

Section 20. Stage Floors

The gridiron shall have a metal lattice floor designed to carry a live load of 75 pounds per sq. ft. Fly galleries shall be of fireproof construction designed to carry 90 pounds per sq. ft. All of the stage except the part usually covered by floor traps of no greater width than the proscenium opening and depth from proscenium to rear wall shall be of fireproof construction. The non-fireproof part shall be of heavy timber or steel beam construction. All shall be designed to carry at least 100 pounds live load per sq. ft.

Section 21. Projection Room

Every projection room shall be large enough to permit the projectionist to walk freely on three sides of the machine. Walls shall be of concrete or tile at least 4 inches thick and all doors leading from the room to be self-closing fire doors. Openings for picture projection shall be protected with heavy sheet metal drops arranged to slide in grooves. They shall be controlled by cords arranged in

such a manner that they will automatically close at the outbreak of fire. All shelving and fittings shall be of incombustible material and all films not in use shall be kept in tight-covered metal cans. There shall be a ventilator at least 12 inches in diameter leading from the top of the room to the outside air.

Conclusion

If these requirements are carefully followed out in the planning of a theatre, it would appear that the building should be safe. The fallacy of this was proved by the Iroquois disaster in Chicago. This theatre was the last word in fireproof construction and careful planning. In his paper on "The Safeguard of Life in Theatres," by President John R. Freeman, presented to the American Society of Mechanical Engineers, he states: "At the time of the fire in the Iroquois, that fire pails and soda water fire extinguishers were absent and that ventilating skylights over the stage were blocked so that they could not slide open, and that exits were poorly marked, and that there was a delay in providing the fire hose on the stage."

Therefore, combined with these standard requirements, must be the careful attention by the management as well as frequent and efficient inspection by the authorities. On account of the many places on a theatre stage and adjoining property rooms where rubbish and junk may accumulate without being noticed because of the lack of light, it is very necessary that the management exercise constant vigilance to prevent the danger of fire.

In defense of some of the old non-fireproof theatres one might say that as far as safety to the audience is concerned, it is far better to have very clear and intelligent planning, such that the patrons can easily find their way out, than absolute fireproof construction, as the great loss of life has usually happened within five minutes of the first flame. So, if a theatre can be emptied in two to three minutes, the audience will hardly suffer even if the building is of ordinary construction. In the Iroquois, the underwriter loss was practically nothing while the human toll was enormous. Mr. E. O. Sachs, the London architect, in his account of some one thousand theatre fires, states that the requirements of safety to the audience should be placed in the following order: "Good planning first, efficient and constant watching by the management, careful and frequent inspection, and fire-resisting construction last."

At present untold sums are being spent for theatres. Each new building being larger or more lavishly decorated than any other. Picture presentation has developed into one of the highest arts, requiring wonderful stage settings, orchestration and lighting effects. The management is constantly on the alert to invent something new to provide amusement and enjoyment for their patrons.

The Interior Illumination of the Motion-Picture Theatre

By L. A. Jones

The desirability of providing sufficient illumination for the convenience and comfort of the audience, if this can be accomplished without perceptible loss of quality in the projected picture, is obvious. It is scarcely necessary to enumerate the many serious objections to the use of very dimly lighted rooms in which motion pictures are being exhibited to large audiences. The difficulty encountered by persons entering from the relatively brightly lighted exterior regions in finding their way to unoccupied seats is considerable. The undue strain thrown upon the accommodation processes of the retina resulting from a sudden transition from a brightly lighted exterior to a dark interior, or vice versa, is very objectionable and to be avoided if possible. More serious than these, however, is the excessive visual fatigue and eye-strain resulting from a prolonged observation of a brightly illuminated area (such as the screen on which the picture is being projected) occupying but a small portion of the field of view and surrounded by very dark areas, this condition being ideal for the production of glare effects due to excessive contrasts. It is evident for the satisfactory exhibition of motion pictures that the general illumination in the theater must be subdued in order that the projected picture shall be of good quality as regards its apparent brightness and contrast, and that in raising the value of the general room illumination there is a limit beyond which it is impossible to go without seriously affecting these characteristics of the picture. However, it has been found by proper distribution of the light that the general room illumination can be raised to a value sufficient to eliminate all of the objections to a dimly lighted theatre and at the same time produce no perceptible injurious effect upon the quality of the projected picture.

The object, therefore, with which this work was undertaken was the determination of the maximum value of general illumination allowable in a theatre when motion pictures are being exhibited, this allowable maximum being defined as the highest value of general illumination which will not cause any appreciable diminution of apparent contrast in the projected picture. From a consideration of the fundamental data available relative to the various retinal sensibilities, it is possible to draw certain general conclusions as to the most desirable conditions of illumination for this purpose. The data available, however, are not sufficiently complete to permit the computation of the desired values, and hence it was necessary to resort to experiment and actually to measure in an experimental installation the illumination which was found to be permissible without causing loss of quality in the projected picture.

Before proceeding with an account of the experimental work, it may be well to consider briefly the general theory of the subject, and the fundamental characteristics of the eye which are important in problems of this nature. First of all, it should be borne

in mind that the sensation produced when light falls upon the retina depends upon several factors, such as the intensity of the light, the length of time during which the stimulation continues, wave-length of the radiation, the size and shape of the retinal area stimulated, and the physiological conditions of the retina due to previous action of light upon it. It is sufficient for the present purpose to consider only the reactions of the retina to the intensity factors of the stimulus and neglect those which are functions of its quality.

Of first importance among the factors requiring consideration is the sensibility of the retina to brightness. There are three types of brightness sensibility: (1) threshold sensibility, which is measured by the least brightness perceptible; (2) contrast sensibility, which is measured by the least brightness difference perceptible; and (3) glare sensibility, which is measured by the brightness just sufficient to produce discomfort when observed.

Now the sensibility of the eye to brightness, contrast, and glare depends upon the condition of the retina at the particular time the determination is made, and that condition is in turn dependent upon the previous stimulation. Hence, it is necessary to specify the condition of the retina at the time the measurement of sensibility is made. This is done by specifying the brightness to which the eye is adapted, and is termed the "adaptation level" of the retina. For instance, when an observer looks for some time (10 to 30 minutes) at a uniformly illuminated surface so large as practically to fill the field of vision, a condition of equilibrium in the retinal process is reached, and the observer's eye is said to be adapted to the brightness of the field, and his "adaptation level" is specified by stating the brightness of the illuminated surface, which is sometimes termed the "sensitizing field." It is found that the sensibility of the retina varies over very wide limits depending upon the adaptation level; in fact due to this variable sensibility it is able to operate over a range of brightness from 1 to 100,000,000 (approximately). A complete expression of sensibility therefore requires measurement over the entire adaptation range, and the results are most conveniently expressed in graphic form as curves plotted with values of the various types of sensibility (threshold, contrast, and glare) as ordinates and the adaptation level as abscissae. These three sensibility curves are given in Fig. 1.*

Since the variation in value of adaptation level (field brightness) is enormous, it is necessary in plotting the curves to use the logarithms of these values. The ordinates are expressed in units appropriate to the various types of sensibility. For any specified adaptation level, it is now possible to read from the curves the brightness which is just uncomfortable (producing glare), the least perceptible difference in brightness (contrast), and the least perceptible brightness (threshold). Applying this to the case of an

* Nutting, P. G., The Fundamental Principles of Good Lighting, J. Frank. Inst., 183: 1917, p. 287.

Blanchard, Julian, The Brightness Sensibility of the Retina, Phys. Rev., XI, No. 2, 1918, p. 81.

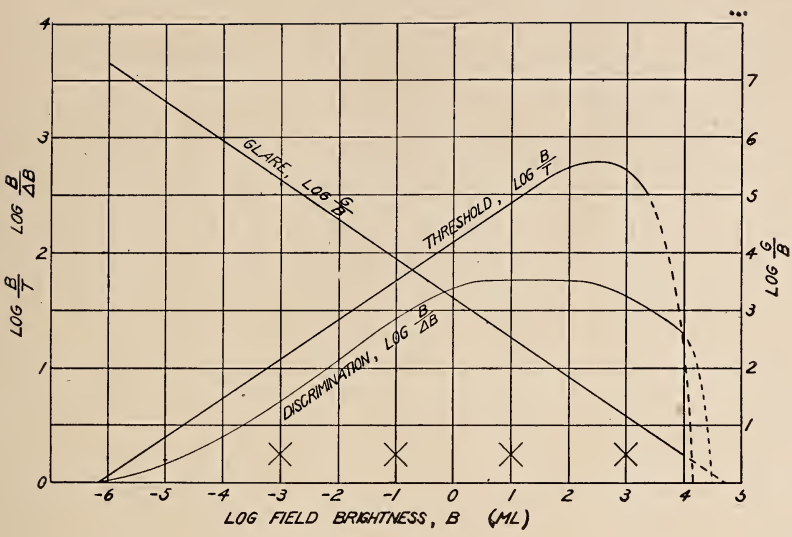


Fig. 1.

observer in a motion-picture theater, we are able if his adaptation level is known to find to what extent any area may be illuminated without producing glare, to compute the amount of general illumination which may be tolerated on the screen without producing a perceptible degradation of contrast, or to specify the maximum of brightness difference in the field of vision if undue eye fatigue is to be avoided.

In order to make such useful application of the fundamental data contained in the sensibility curves, it is, however, necessary to know the adaptation level of the observer under the particular conditions considered. Unfortunately the data necessary for this are not at present available. It will be recalled that the "adaptation level" is defined as specified by the brightness of a uniformly illuminated field filling the entire field of vision, and the retinal sensibilities were determined under such conditions. Now it is probable that the brightness of the foveal image is the most important factor in fixing the adaptation level of the retina, but undoubtedly the brightness of the images outside of the fovea have some influence. In the case of a person watching a motion picture, the picture itself occupies but a relatively small portion of the visual field, and in case the surrounding areas are very low in brightness his adaptation level will probably be somewhat lower than indicated by the average picture brightness. The effective application of the sensibility data, therefore, depends upon a reliable determination of the adaptation level under practical working conditions in the motion-picture theater. An instrument is at present being developed with which the adaptation level of the retina when stimulated by non-uniform fields may be measured. It is hoped when such measurements are available that the application of the sensibility data will

lend additional support to the conclusions reached in the experimental work to be described in the following pages.

In order to make an actual determination of the maximum general illumination permissible, an experimental lighting system was installed in the Projection Room in the Research Laboratory. In designing this system an attempt was made to obtain the maximum average illumination on the table plane (horizontal surface 30 inches above the floor) with a minimum of illumination on the projection screen, and further to distribute the light so that no area either of wall, ceiling, or lighting fixture should be sufficiently bright to

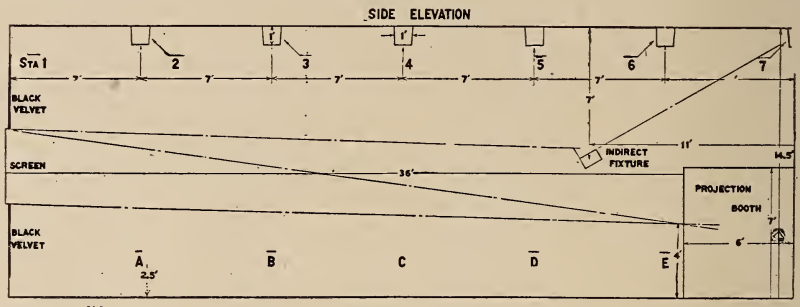


Fig. 2.

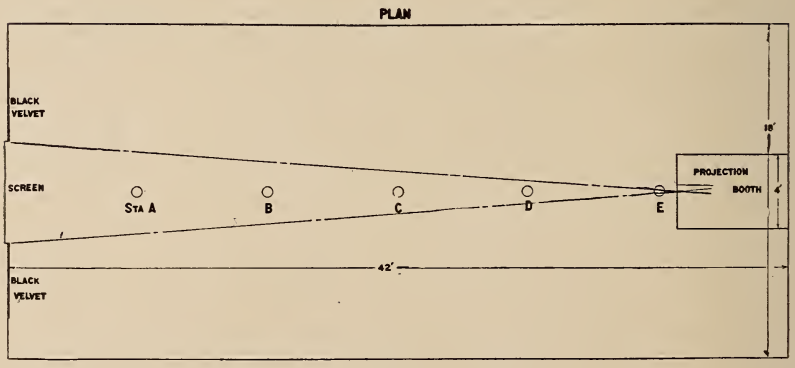


Fig. 3.

cause glare or appreciable increase in the adaptation level of the observer.

In Fig. 2 is shown a side elevation of the room with the locations of the various elements of interest in this problem and the dimensions of importance. In Fig. 3 is given a plan view and in Fig. 4 an end elevation showing screen with its surrounding frame of black velvet. The ceiling of this room is painted white, while the walls are a medium tone of buff. The projection screen is of the metallic type (Gaumont), having a high reflecting power for points on and near the axis, but falling off rapidly for angles of greater than 15° from the axis.

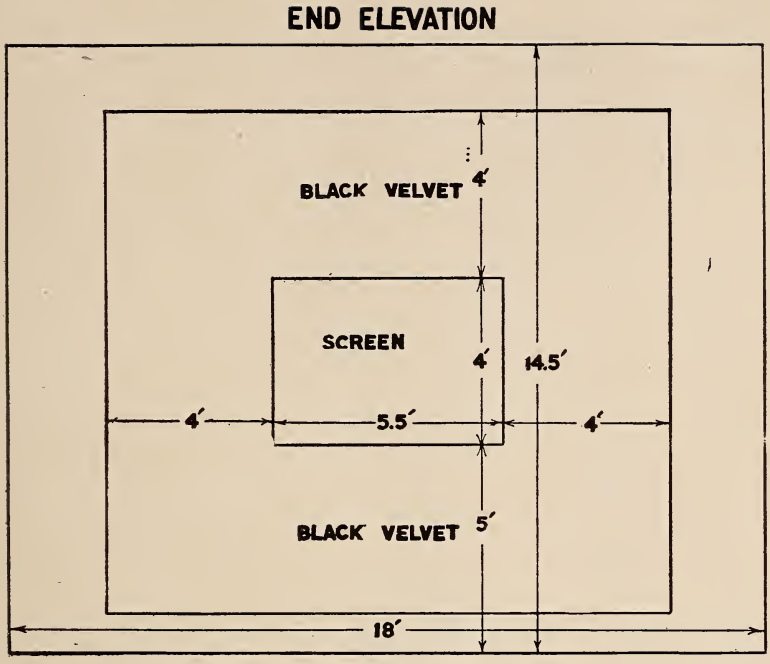


Fig. 4.

The lighting fixture was constructed by mounting six 10 x 12 darkroom ceiling lamps on a light wooden frame work. In order that the position of this fixture could be adjusted to give various distribution of the light, it was suspended as shown in Fig. 5.

The vertical members *AA* carry the horizontal member *B*, which is a cylindrical metal rod about 21 feet long. One of these fixtures is mounted near each side of the room, and parallel to each other. Upon these horizontal ways operate the sliding carriages *C*. Over small pulleys attached to this carriage, the sash cords *FF* operate and suspend the lighting fixture as shown. By

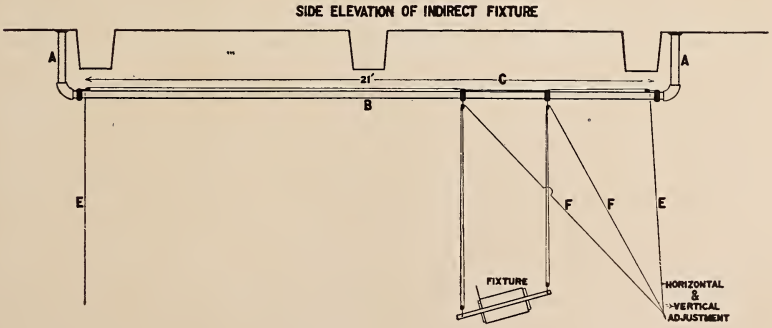


Fig. 5.

means of these adjustments, it is possible to adjust the position of the lighting fixtures to any desired distance from the ceiling, to vary its distance from the projection screen by a considerable amount and further to vary the inclination at which the fixture hangs thus controlling to a great extent the distribution of the light from the fixture.

Complete diffusion of the light from the incandescent lamps mounted in the fixture was obtained by inserting a sheet of 10 x 12 opal glass in the position provided for holding the safelight. This material is of such nature that the light transmitted is very completely diffused. In the projection booth is situated a projection machine of the ordinary type. An arc current of 25 amperes was used throughout the tests recorded in this report. With this current the screen brightness as measured with the machine running but without a picture in position was found to be approximately 20 milli-lamberts. This measurement was made from a point very near to the axis of projection and due to the character of the screen was much higher than the brightness measurement made from points a few degrees from the axis. From measurements made previously in several of the motion-picture theatres in Rochester, an average value of screen brightness under similar conditions was found to be approximately 15 milli-lamberts. The screen brightness used in these experiments therefore is somewhat higher than is ordinarily met with in practice.

The lighting fixtures having been installed, the procedure followed was to determine by trial and error the maximum amount of light which it was possible to use without causing an appreciable loss of quality in the picture. After several preliminary trials it was decided that the best result was obtained by placing 60-watt lamps in the four central elements of the fixture and 40-watt lamps in each of the end boxes, the entire 10 x 12 surface of the diffusing glass being uncovered and used as effective source area. The position of the fixture which was found to give a very satisfactory distribution of the light was as indicated in Fig. II. This position was approximately five feet from the ceiling and eleven feet from the rear wall of the room, and with the fixture inclined forward so as to give an evenly graduated distribution of the light on the ceiling. It was found necessary in order to prevent excessive illumination of the screen by the light from the fixture to place a cardboard screen along the front of the frame carrying the safelight fixtures. This was of such dimensions that no direct light from the opal glass was permitted to fall upon the projection screen, and served also to reflect some of the light backward, so that the ceiling brightness at the rear of the room was brought up to a value more nearly equal to that of the brightness of the ceiling directly above the fixture.

This arrangement having been arrived at and considered satisfactory, several experienced observers were asked to express opinions as to whether or not the quality of the projected picture was seriously affected by the presence of this general room illumination.

By observing the screen with the eyes so shielded that nothing but the picture could be seen, the ceiling lights were alternately turned off and on, and the effect upon the quality of the picture observed. While it is possible to detect a slight veiling of the deeper shadows when the room illumination is being used, the effect is so slight as to be inappreciable in causing a degradation of the contrast of the picture.

Undoubtedly the veiling illumination falling upon the screen from the general illumination in the room is sufficient to cause an easily measurable decrease in actual contrast of the picture. Actual observation, however, shows that this decrease in contrast is not apparent to the observer. The explanation of why this decrease in contrast produces such a small apparent effect is of considerable interest, and is, in fact, of fundamental importance. The explanation lies in the fact that the contrast sensibility of the retina increases as the adaptation level rises. The presence of the general room illumination is responsible for a rise in the adaptation level of the observer, and the corresponding increase in contrast sensibility permits the perception of smaller brightness differences. If in the projected picture a constant contrast has been maintained, this increase in contrast sensibility would tend to make the picture look more contrasty, but since the presence of veiling glare tends to decrease the actual contrast, the two effects work in opposite directions and tend to compensate each other, the result being no perceptible change in apparent contrast.

On the whole this arrangement was considered very satisfactory by all those observing. One point of interest noted was that much less visual discomfort resulted when the screen brightness was suddenly changed by the appearance of the title region of the film, and further that a slight residual flicker due to lack of precise shutter adjustment was less noticeable. In fact much less general eye fatigue resulted when the room lights were on than when they were turned off.

In order then that a permanent record of the quantity and distribution of illumination used might be obtained, a series of brightness and illumination measurements were made. For this purpose the Macbeth illuminometer properly calibrated was used. The points at which measurements were made are indicated in Fig. 2. The stations *A, B, C, D,* and *E,* represent points on the table plane, that is, 30 inches from the floor, while the stations, 1, 2, 3, 4, 5, 6, and 7 are situated at various points on the ceiling as indicated by the arrows and represent the points of maximum brightness as seen by an observer situated at a point near station *D*. All values of brightness are expressed in milli-lamberts (m. l.) and those of illumination in foot candles (f. c.). In order that a complete analysis of the distribution of the light might be made, sets of measurements were made under four conditions of illuminations as follows:

I. Ceiling lights on. Arc not operating.

II. Ceiling lights on and arc operating. No picture in the machine.

III. Arc operating, no picture, no ceiling lights.

IV. Ceiling lights and arc with picture.

The measurements obtained under I. indicate the intensity and distribution of the light from the installed fixture. The data in III. represent the intensities and distribution of the light reflected from the screen when the arc is operating but with no picture in the machine. The data in IV. are of greatest interest, as they represent the distribution and intensity of the illumination under actual operating conditions, the sources of light being both the installed fixture and the light reflected from the projection screen. The data in II. were recorded as being of interest in indicating the difference between the illumination with and without a picture in the projecting machine.

The measurements having been completed with this arrangement of the lighting fixture, it was decided to make a second adjustment and to repeat the measurements with slightly changed conditions. The distance between the fixture and ceiling was increased to 7 feet, and the inclination changed somewhat so that while the projection screen was protected from direct light a higher ceiling brightness near the front of the room was obtained. The photometric measurements were then repeated from the same set of groupings as employed previously. The data on the two arrangements of the lighting system are recorded in Table I. A detailed consideration of this table will not be given at this time.

In order to present this data in more graphic form, the values of brightness and illumination are written in at the proper position on prints showing the side elevation of the room, and a brief consideration of these will be taken up. The conditions obtained with the second arrangement of the fixture were somewhat more satisfactory than the former, hence our attention will be confined entirely to the values obtained with this more favorable arrangement.

In Fig. 6 the data obtained with the ceiling lights on but without the projection arc are shown. It will be noted that the maximum ceiling brightness is obtained slightly in front of the fixture, the maximum being 1.9 ml. This brightness decreases gradually toward the front of the projection room. The illumination on the table plane due to this source is indicated by the figures at stations *A, B, C, D,* and *E.*

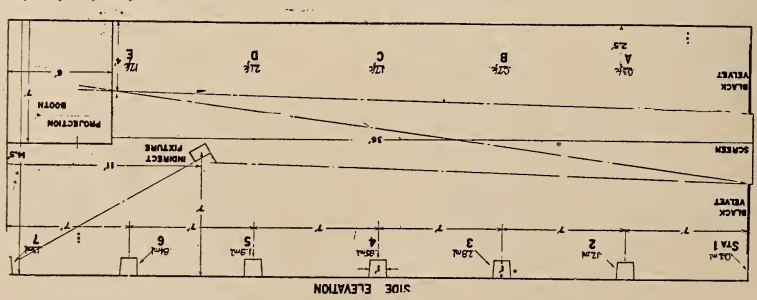


Fig. 6.

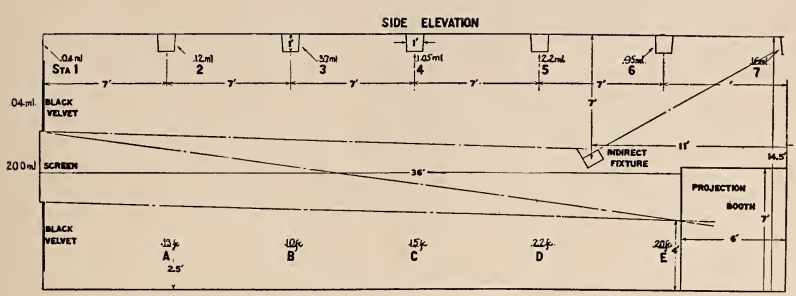


Fig. 7.

In Fig. 7 brightness and illumination values at corresponding stations are shown, the condition being that ceiling lights were on and the projection machine operating but without a picture in the machine. A comparison of these values with those in the previous figure shows the magnitude of the illumination resulting from the light reflected from the projection screen, its influence being most marked near the front of the room. This is more clearly shown by Fig. 8, in which the measurements of illumination due to the light reflected from the projection screen alone are indicated.

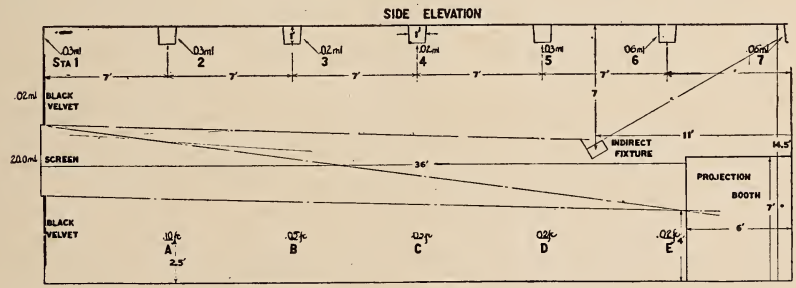


Fig. 8.

The data of greatest interest, however, are shown in Fig. 9, these being the values obtained by taking measurements under actual operating conditions, that is, with the projection machine operated in the usual way with a picture of normal density and the lights providing the general room illumination turned on. It will be noted that the ceiling brightness is relatively high near the rear of the room, its maximum being 1.8 ml. This brightness decreases to a value of .04 ml. directly above the projection screen. The illumination on the table plane is also high at the rear of the room at a maximum value of .19 f. c. and a minimum value of .06 near the front.

This arrangement of the room illumination was found to be entirely satisfactory from the standpoint of the picture quality. No appreciable diminution in the apparent contrast or brightness

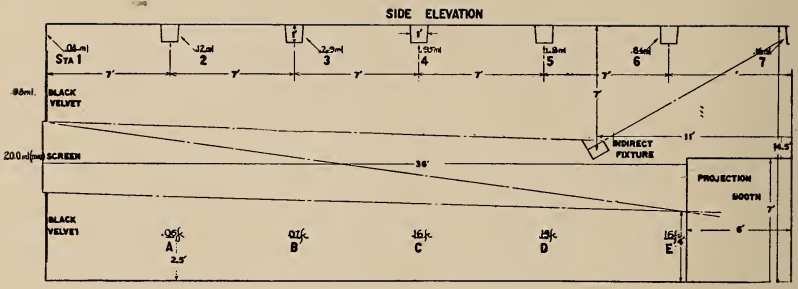


Fig. 9.

of the picture was perceptible. With this illumination it is quite possible after becoming accommodated to the existing brightness level to read with comfort ordinary newspaper print, and furthermore the length of time required for accommodation is very short. For instance, an observer entering the room with eyes adapted to full exterior daylight levels can see immediately every detail of furniture in the room and a period of not more than one or two minutes is necessary for adaptation sufficient to read with ease ordinary printed material.

The general conclusions to be drawn from these experiments are that a relatively large amount of general illumination may exist in motion-picture theaters without appreciably affecting the quality of the projected picture, provided that this illumination is properly distributed.

In Fig. 10 is shown a possible arrangement of the lighting system which would give a highly satisfactory theater illumination. This plan is presented as illustrative of one way of handling the problem and undoubtedly many others may be worked out.

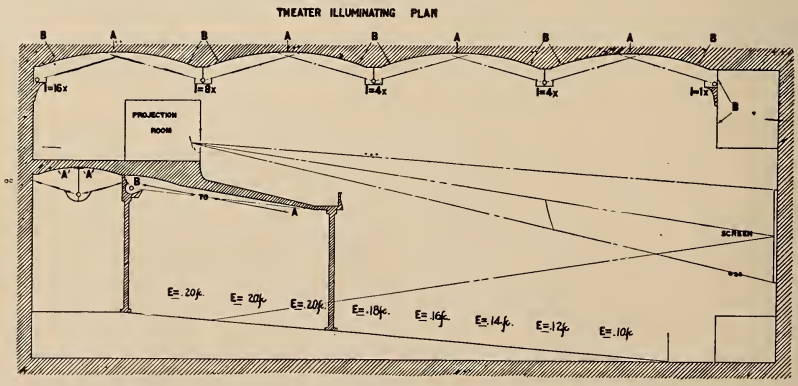


Fig. 10.

The ceiling which consists of four arches or concavely curved surfaces is illuminated by lamps inclosed in the fixtures, which are designed to appear as integral parts of the beam structure, as

indicated. The intensity of the various lights is distributed roughly as indicated by the numbers i = ix, i = 4x, etc. This would result in a relatively high ceiling brightness at the rear of the theater and a relatively low value at the front. Since the lamps themselves must be placed comparatively close to the ceiling, it would be necessary in order to obtain an approximately uniformly graded ceiling brightness, to arrange the decorative scheme applied to the ceiling so that the regions marked *B* should have a relatively low reflecting power, while those marked *A*, on the other hand, would have a very high reflective power. The details of some such decorative systems have been worked out, but they will not be considered at this time. The lighting of the ceiling underneath the gallery is obtained from lamps at *B* and here again the ceiling reflecting power should vary from a low value at *B* to a high value at *A*.

From the result of the experiments in the projection room, it has been concluded that the illumination on the table plane at various points in the theater should be approximately as indicated by the values of *E*, and the number and size of the light units used should be so adjusted as to give the indicated values. While an approximate computation could be made indicating the number and size of units necessary, it would be quite impossible without detailed information of the dimensions of the room, the reflecting power of various surfaces, and the exact positions of the lamps to make a definite estimate as to the total quantity of light flux necessary.

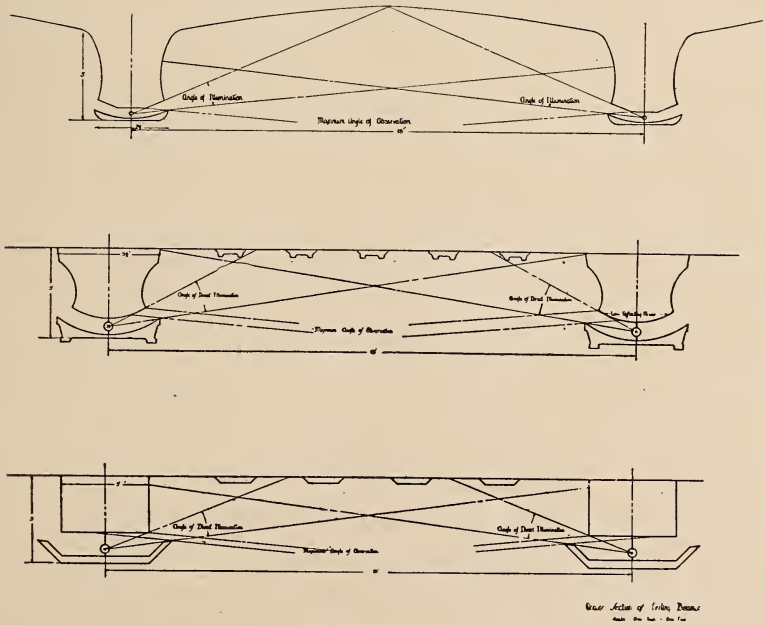


Fig. 11.

In Fig. 11 are shown three cross-sectional diagrams illustrating the possibilities in beam design which would result in the proper distribution of the light flux over the ceiling. These designs, of course, are only given as suggestions of what might be done in arranging an indirect system of illumination conforming with the conditions outlined in this report. The beam structure adopted in any particular case will be influenced to a great extent by the architectural style of the theater and the diagram given serves only to suggest a method of concealing the lamp within the beam structure and at the same time obtaining the proper illumination of the ceiling.

It should be mentioned also that the illumination in the lobby and in the various vestibules and extreme rear of the theater should be so arranged that a person entering the theater passes gradually from the illumination of the exterior to that of the body of the theater. That is, the transition from exterior brightness level to the interior brightness level should be made in a series of gradual steps rather than in a single abrupt step.

Returning again to a consideration of the brightness of the frame surrounding a picture, it was found by experiment that raising the brightness of the frame to a value of approximately .02 m. l. gave a much more pleasing effect than when the black velvet frame was used in which case the brightness was so low as to be beyond the limit of measurement with the instrument available. The contrast between the frame and the highlight of the projected picture, which is estimated to have been about 1 to 10,000 in case of the black velvet frame was found to give rise to a certain feeling of visual fatigue and discomfort. By covering the velvet with a draping of white mill net the reflecting power was increased to such an extent that the contrast between the frame and picture was considerably reduced. It will be noted that the average screen brightness without any picture in the screen is found to be 20 m. l. The average screen brightness with a normal film in position is probably of the order of 2 m. l. while the maximum may be taken to be somewhere in the neighborhood of 10 m. l. With a frame brightness of from .02 to .03 as indicated by the data, the maximum contrast between picture and frame is reduced to less than 1 to 1,000, while the average contrast is approximately 1 to 100. Now the sensitometric data on glare indicate that with the eye adapted to ordinary daylight levels a contrast of over 1 to 100 results in glare or undue fatigue. However, with the eye adapted to lower levels, the allowable contrast increases to a considerable extent and if (See Fig. 1) we assume an adaptation level of 1 m. l. the data indicate that contrast as great as 1 to 1,000 may occur in the visual field without resulting in glare or undue visual discomfort. Contrast greater than this, however, should not be permitted. These results indicate that in general a black frame should not be used, but that a much more pleasing and less fatiguing arrangement will be obtained by the use of the frame of somewhat higher reflecting power.

The general conclusions are, therefore, as follows:

By proper distribution of the light, the general illumination of the interior of a motion picture theater may be raised to a considerable extent above the values in common use without causing any appreciable loss of quality in the projected picture. The illumination on the table plane in fact may be raised to the point where ordinary news print can be read with ease by an eye adapted to the existing brightness level.

While it is impossible to outline specific instructions for particular cases without detailed knowledge of such factors as dimensions and architectural details of the room, the reflecting power of the various ceiling and wall surfaces, and the position of the light fixtures, the following general principles may be outlined.

(1) The illumination on the table plane should vary from .10 foot candles at the front of the theater to .20 foot candles at the rear.

(2) No area (outside of the projected picture) visible from any seat in the theater should have a brightness of more than 2.5 to 3.0 m. l.

(3) The attainment of (1) without exceeding the values mentioned in (2) requires the use of very extended effective sources such as illuminated ceiling and walls and is best accomplished by the use of an indirect system of lighting.

(4) All light sources and fixtures such as diffusing globes and translucent glass ware having a surface brightness of more than 2.5 to 3.0 apparent milli-lamberts should be entirely concealed from view.

(5) It should be noted that a sheet of white paper illuminated by a 25-watt lamp at a distance of 12 inches has an approximate brightness of 20 milli-lamberts. A sheet of music, therefore, illuminated in this way if visible becomes a glare spot and may cause great discomfort to the audience. Arrangements should therefore be made which, while providing adequate illumination for the musicians in the orchestra, will prevent the illuminated music sheets from being visible to the audience.

(6) The contrast between the highest light of the picture and the surrounding frame should be less than 1 to 1,000, preferably less than 1 to 500. Black frames should, therefore be avoided, one of a neutral gray being much preferable.

(7) Lighting of lobby, vestibules, etc., should be so arranged that the transition from the brightness level of the exterior to that of the interior, or vice versa, is accomplished by a series of small differences rather than by a single large one. Such arrangement will to a great extent eliminate the visual shock which accompanies a sudden change in the intensity of the visual stimulus.

(8) The use of a projection screen set well back on the stage and thus shielded to a great extent from the light reflected from

ceiling and walls would probably permit the use of even greater room illumination than was used in these experiments.

Table

		Ceiling Brightness							Illumination on Table Plane, Screen and Frame						
		1	2	3	4	5	6	7	A	B	C	D	E	S	F
I.	A	.02	.05	.14	.84	2.7	1.2	1.4	.02	.05	.10	.15	.19	.02	.01
II.	A	.03	.07	.14	.84	2.6	1.3	.18	.15	.09	.15	.15	.17	20.00	.03
III.	A	.03	.03	.02	.02	.03	.06	.05	.10	.05	.03	.03	.03	20.00	.02
IV.	A	.02	.04	.14	.84	2.3	1.3	.15	.04	.04	.13	.15	.19	10.00	.02
I.	B	.04	.12	.28	.95	1.9	.84	.15	.03	.07	.17	.21	.17	.04	.02
II.	B	.04	.12	.37	1.05	2.2	.95	.16	.13	.10	.15	.22	.20	20.00	.04
III.	B	.03	.03	.02	.02	.03	.06	.05	.10	.05	.03	.02	.02	20.00	.02
IV.	B	.04	.12	.29	.95	1.8	.84	.16	.06	.07	.16	.19	.16	10.00	.03

I. Ceiling Lights On, Arc Not Operating.
II. Ceiling Lights On, Arc Operating, No Picture.
III. Ceiling Lights Off, Arc Operating, No Picture.
IV. Ceiling Lights On, Arc, Picture on Screen.

Continuous Motion-Picture Machines

By C. Francis Jenkins

America's supremacy comes about by reason of her social-economic engines. She has given the world more mechanisms to do what had theretofore been done by hand, than all other countries combined; and because we are great folks to love our neighbors, some of our most brilliant efforts have been to facilitate intercourse, for intercourse means friendliness. So we have given the world instruments to promote sociability, the telegraph, the telephone, the typewriter, the talking machine, the typesetting machine, and now we add the motion-picture machine to hasten our means of knowing each other.

The motion picture, as applied to the picture theatre, is already the fifth largest industry. When to this is added the much wider field outside the theatre, it is not beyond the range of probability that motion pictures will become the largest single industry in the world. And this probability is strengthened by the fact that the motion picture film is standard the world over. Not only is it the only world standard, but it is unique in other ways. For example:

It is a curious anomaly that in the motion-picture projecting machine business, the usual rule of supply and demand does not hold good. One may buy anything else, a watch, an automobile, a house, paying as much or as little as one chooses, getting increased value with increased cost, but for a motion-picture projector one pays about the same price for all makes.

There is not today a picture equipment comparable with the magnificence of a great many of the theatres already built and many more projected. No matter how much the builder of a fine theatre may desire it, he cannot get a correspondingly fine picture equipment; it doesn't exist; the only machine available is the same cheap-priced, old style machine used in the little five-cent movie house.

The theatre owner may pay as much or as little as he likes for music and other accessories, but when it comes to the picture machine, that which produces the thing he sells to the public, he is limited to a very small choice, a choice in name mostly, for the three or four machines available all sell for about the same price.

The reason for this is that the old-style longitudinal projector has inherent limitations, and has been developed just about as far as it is possible to go. For added cost one gets more cast iron only, the quality of the picture on the screen is not noticeably different.

This inherent limitation is the intermittently moved film, for the same reason that reciprocation limits the use of the steam engine. One does not think of fractional steam motors, for example, though we all find daily use for small continuous rotation electric motors.

Of course, such reasoning applied to motion-picture machines leads us directly to a study of the continuous motion film projector, a subject from which motion-picture engineers shy, as scientists used to shy at the subject of flying machines. But that way is the road out of our projection difficulties, and any investigation and

experimentation along that line is worth while and this is my warrant for presenting the following description of a new contribution to the subject.

Everyone readily admits the advantages to be gained by the employment of continuous instead of intermittently moved film. Striking advantages are immediately suggested: (1) Longer life for the film, consequently larger revenue from each print; (2) 100% increase in lighting efficiency, i. e., the same screen lighting with 50% of the present light source intensity; (3) a noiseless and much less complicated projecting machine; and, (4) almost unlimited speed (not for the projectionist, many of them need a speed-limiting brake), but continuous motion in a camera permits such speeds as open up possibilities for scientific research not available in any other way. Sharp, clear, discrete pictures at a rate of 50,000 per minute are possible with fast lenses and super-sensitive film now available if suitable film-handling mechanism could be found. Such pictures subsequently projected at normal speed, say 1,000 pictures per minute, are destined to disclose many things impossible of discovery without such apparatus.

Many attempts to attain this ideal machine have appeared from time to time and hundreds of patents have been granted thereon, but most of them propose continuous motion of the film while employing intermittent or reciprocating mechanism. This is not, and cannot be the solution of the problem, for the parts moving intermittently are a greater handicap than the film, because they are many times heavier than that part of the film having step-by-step motion, and we are no better off than before, being still limited to the restricted speeds inherent in intermittent mechanisms.

In my initial work of thirty years ago, I employed both continuous and intermittent motion mechanisms. The intermittent first got general public acceptance because it was the easiest and cheapest made, and this and all subsequent mechanisms the world over are basicly alike in principle and curiously alike in construction, for example, all are built left-handed.

Of machines having continuous motion of both film and mechanism, the only example of my own ever attaining any considerable degree of speed and picture perfection employed continuously moving film and a plurality of lenses following each other in sequence and single line procession across a stationary shutter opening, which, as you will observe, is exactly the reverse of the intermittent mechanism in which the shutter is in continuous rotation while the lens and film are stationary at the instant of exposure.

But the cost of this large number of lenses and the difficulty of getting them matched gave the intermittent projector the long start it has maintained to this day, though an examination of the old apparatus in its various forms on exhibit in the U. S. National Museum where it was put some twenty-six years ago is interesting from other than an historical point of view. The number of different and unprofitable ways a basketball of expensive lenses can be put

together again suggests the old proverb that "a fool and his money are soon parted."

Therefore, the contribution to the art which I shall describe herein is the result of experimentation with the object of producing a less expensive machine, while keeping in mind all the time, the absolute necessity of employing (1) standard film; (2) stock lenses and light sources; and (3) continuous motion of every part of both

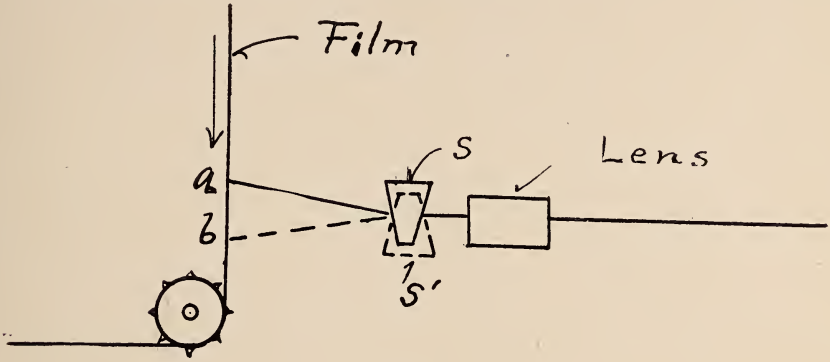


Fig. 1.

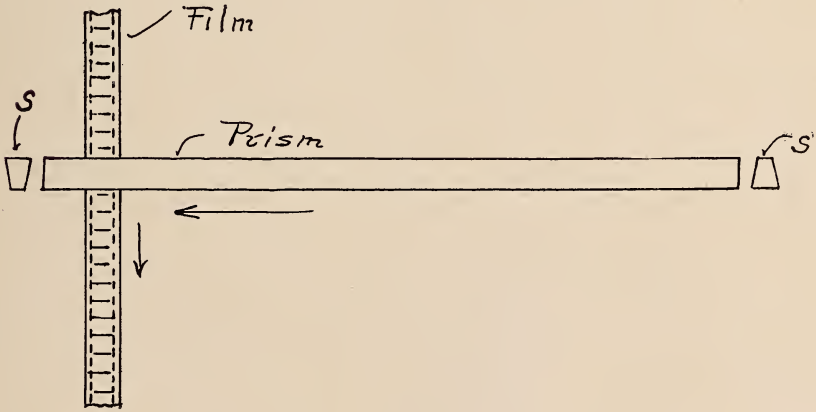


Fig. 2.

film and mechanism. As to the success attained I shall leave you to judge for yourself from your own observation of machine and screen picture.

This machine, considered first as a camera, is built on the principle that if a ray of light coming from a distant point could be bent just after passing through the lens so that it would impinge on the film at an initial position, that is, at the top of the aperture, and should then be caused to travel down one frame in exact syn-

chronism with the movement of the film, our problem would be solved.

This bending of the ray of light just after passing through the lens can be accomplished by interposing a prism, say of 5 degree angle, with its base up (S, Fig. 1) which will project the ray to

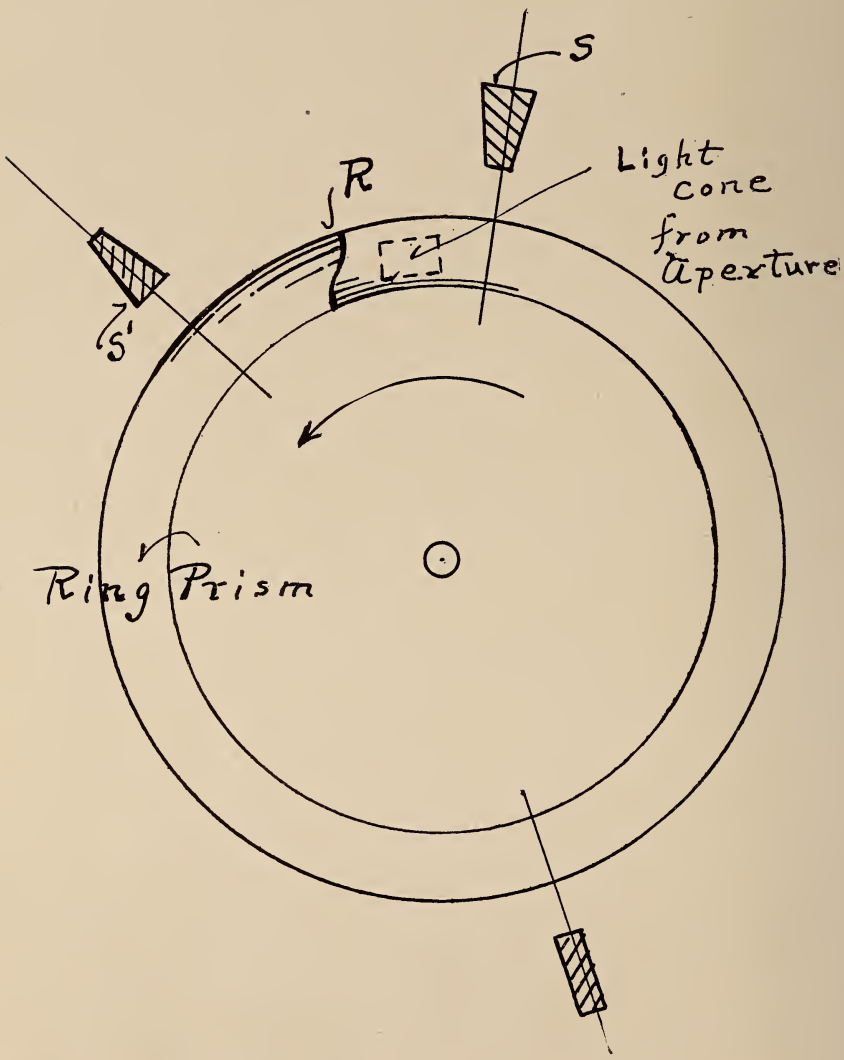


Fig. 3.

its initial position (a) at the top of the picture aperture; and finally with its base down (S′, Fig. 1) to project the ray to its final position (b) at the bottom of the aperture, that is, the end of the down-

ward travel of the film. Obviously at the moment the ray passes the middle of the aperture it is not bent at all, and, therefore, the "prism" cannot be a prism at this point but only a plain parallel-sided piece of glass.

The light ray acts as though it were hinged at the location of the prism. If, therefore, we could make a solid glass prism and endow it with the ability to automatically change the angle of its faces in synchronism wth the movement of the film, the ray of light or the picture-carrying cone of light would follow the film, which is exactly the object we seek.

Such an assumption seems paradoxical, but it may be accomplished by employing a long strip of glass prism section with the base up at one end and base down at the other end and a gradually changing contour from end to end between these two extremes.

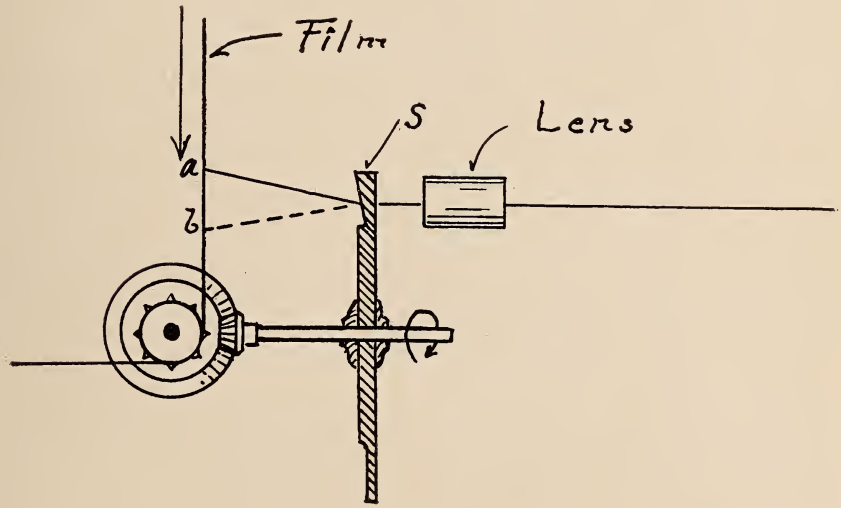


Fig. 4.

(See Fig. 2.) If this strip of glass is passed across the path of the film, in the light cone and in synchronism with the travel of the film, the constantly running film will appear stationary on the screen when used as a projector.

But to make the continuous motion machine of these elements the strip of prismatic glass must be made into a ring (in the plane of its width) with the two ends abutting. When this is done, the contacting ends (R, Fig. 3) represent crossed prisms, one with the base (S) outward and the other with the base (S′) toward the axis of rotation of this ring.

As a matter of convenience in fabrication, this ring prism is actually ground in the face of a disc of glass, as you will observe,

for this then makes its own support on the rotating shaft, upon which it is mounted.

This ring is so geared to the film-feeding sprocket that it makes one revolution with the passage of each single frame across the aperture, and, of course, in exact synchronism therewith. The median line of the prismatic ring, the objective, the picture aperture, and the light source are all located in the axis of the cone of light, the prism being located at the point where the hinging or bending of the light cone is to be effected.

As explained above, the ring makes one complete revolution for the passing of each picture frame, and in synchronism therewith, each frame instantaneously dissolving into the next as the joint in the prism ring crosses the light cone, so that the picture on the screen is stationary, continuous in action and without interruption by shutter blades.

Observe that the machine employs standard film, stock objectives and condensers, and the usual light source, all readily changeable as to size, focus, etc. However, as noted, it does not have the usual fifty-fifty rotating shutter necessary on the intermittent machine, and so the incandescent lamp may be expected to have still further usefulness for there is 100% increase in screen lighting efficiencies.

It is not my intention to suggest that the problem is solved to an extent precluding further improvement, but I do think any work along this line is worth while. Certainly the curious fact that no marked change in projecting machines has been made in twenty-five years would seem to warrant the assumption that there is abundant opportunity for research work.

Further Measurements of Illumination in Motion-Picture Projection

By W. E. Story, Jr.

SYNOPSIS—The method previously described has been improved and applied to the measurement of the total illumination obtained on the screen with different source sizes and different condenser systems compared to the maximum obtainable with the given source brilliancy and given objective diameters. A comparison of the photoelectric measurements with the measurements obtained using an optical photometer for condensers of different absorption and sources of two slightly different brilliancies shows the ratio of the photoelectric cell readings to the photometer readings to be independent of color thru the range considered. Uniformity of screen illumination is also taken up in a general way by the application of direct observation of the screen to the automatically drawn curves registering total illumination.

Since the work described in the last transactions of this Society, new photoelectric cells have been made that are better adapted to the measurements required. Some minor changes have also been made in the rest of the apparatus.

It has been found advisable to substitute a condensing lens for the ground glass immediately beyond the dummy objective. This condenser focuses the film aperture in the window of the cell, thus delivering all the light (barring certain constant losses of reflection and absorption) that falls on the objective to the cell instead of but a small part as did the opal glass. This change has resulted in a reasonably large galvanometer deflection, even when using an opal source as small as two-tenths of an inch square. The new arrangement offers the great advantage of a source the size of which can be changed at will, without change of any other characteristic.

To find the ratio of deflection to light received by the cell, an arrangement was used somewhat different from that previously employed. The condenser was removed from the optical bench as before, but this time the aperture plate was left in the system and covered with a piece of opal glass. If the opal glass is a perfect diffuser, the intensity of the illumination at any point beyond it will be inversely proportional to the square of the distance from the source of illumination to the opal glass, and accordingly by varying the distances and obtaining corresponding galvanometer deflections, the ratio of cell illumination to galvanometer deflection can be tested.

Figure 1 shows a plate made in this way, using a 2½-inch and 1½-inch objective with potentials of 67, 130 and 320 volts on the cell. Unfortunately, the curve made with the 2½-inch objective and 67 volts overlaps the 1½-inch objective—320-volt curve. Where the deflection is very small, a slight variation of the galvanometer zero or error of measurement has, of course, a great effect on the product of the deflection by the square of the distance. The constancy of this product, however, was well within any accuracy we could use in this work. Below is given a table show-

ing the deflections at the various distances for the six curves and the resulting products.

Fig. 2

Volts on Cell		67				130				320			
Objective		2½″		1½″		2½″		1½″		2½″		1½″	
Dist.	(Dist.)2	Defl.	(Dist.)2	Defl.	(Dist)2	Defl.	(Dist)2	Defl.	(Dist)2	Defl.	(Dist)2	Defl.	(Dist)2
9	81	2.35	190.	.87	70 5	3.52	285.	1.345	109.	6.50	526.		
10	100	1.89	189.	.695	69.5	2.84	284.	1.075	107.5	5.22	522.	1.935	193.
11	121	1.57	190.	.57	69.	2 35	284.	.885	107.	4.33	524.	1.625	196.
12	144	1.32	190.	48	69.	1.98	285.	.740	107.	3.63	524.	1.35	194.
13	169	1.12	189.	.41	69.	1.69	286.	.62	105.	3.10	525.	1.145	194.
14	196	.96	188.	.35	69.	1.45	284.	.525	103.	2.66	522.	.99	194.
15	225	.835	187.	.31	70.	1.26	284.	.46	103.	2.315	521.	.855	192.
16	256	.745	190.	.265	68.	1.105	282.	.39	100.	2.035	521.	.75	192.
17	289	.655	187.	.24	70.	.99	286.	.35	105.	1.795	518.	.665	192.
18	324	.595	191.	.215	70.	.98	287.	.32	104.	1.69	525.	.595	193.
19	361	.535	190.	.195	71.	.875	285.	.285	103.	1.45	523.	.53	191.
20	400	.48	192.	.175	70.	.715	286.	.255	102.	1.30	520.	.47	188.
21	441	.44	190.	.155	68.4	.65	286.	.235	104.	1.185	522.	.425	188.
22	484	.39	189.	.14	68.	.60	290.	.21	103.	1.08	523.	.385	187.
23	529	.365	193.	.13	69.	.55	291.	.20	106.	.99	524.	.36	191.
24	576	.34	196.	.12	69.	.50	288.	.185	106.	.905	521.	.335	193.
25	625	.31	194.	.11	69.	.465	290.	.17	106.	.84	525.		
Average			190.		69.		286.		105.		522.		192.

Ratio of Aver. $\frac{190}{69.} = 2.75$ $\frac{286}{105} = 2.73$ $\frac{522}{192} = 2.72$

It will be noticed that there is no tendency for the product to be higher at one end of the curve than at the other. This indicates that the deflection is proportional to the light entering the cell for a given objective size. Since the aperture is focused at the cell window and not on the potassium surface, the area of the potassium lighted will depend on the diameter of the objective. Accordingly, it remains now to find out whether the law of proportionality holds for objectives of different size, for a difference in sensitivity of different parts of the potassium surface would introduce an error into the measurements.

If it is a perfect diffuser, the opal glass covering the film aperture amounts to a source at the aperture and of its size, supplying light to the objective. Now whereas the exact quantity of light supplied an objective by such a source is quite difficult to calculate, it is very easy to find limiting values between which the true value must lie. A source of infinite size will supply to the objective a quantity of light proportional to its area.

$$Q' = AD^2$$

Where A is a constant depending upon the source brilliancy, and D the diameter of the objective.

A very small source will supply an amount

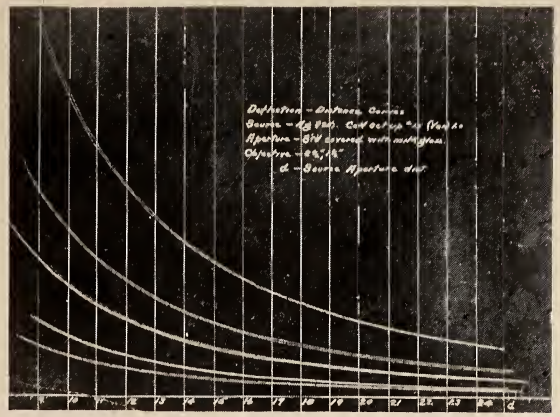
$$Q'' = B\left(1 - \frac{a}{\sqrt{a^2 + \frac{D^2}{4}}}\right)$$

where B depends on the source brilliancy and a is its distance from the objective. The ratio of the amounts supplied to objectives of different diameters will then be in the first case,

$$\frac{Q'_1}{Q'_2} = \frac{D^2_1}{D^2_2}$$

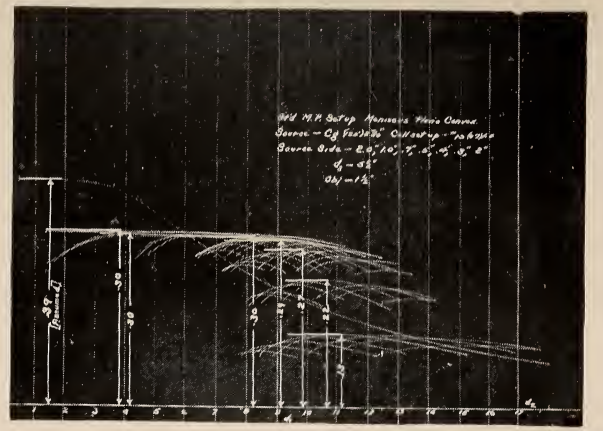
and if we are comparing the 1½-inch diameter objective with the 2½-inch we get

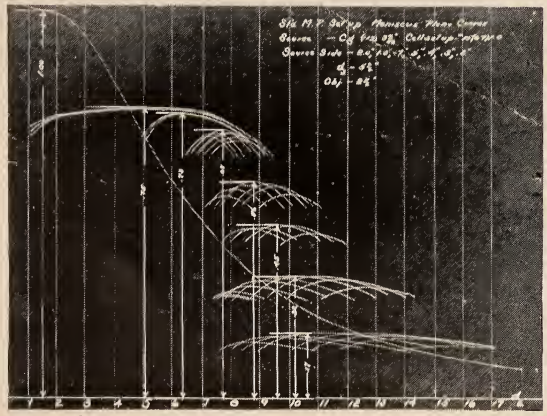
$$\frac{Q'_1}{Q'_2} = \frac{25}{9} = 2.78$$



Left: Fig. 1

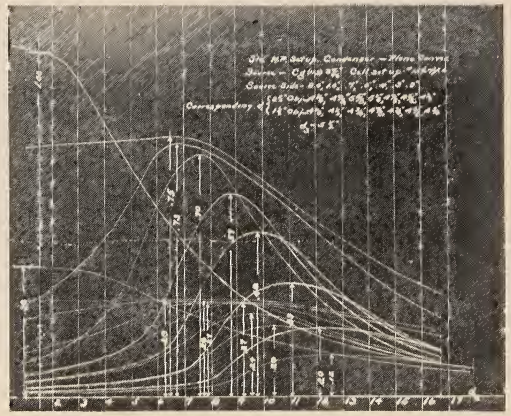
Right: Fig.4





Left: Fig. 3

Right: Fig. 6



In the second case by inserting the value of 5½ for both a_1 and a_2 and 2½ and 1½ for D_1 and D_2.

$$\frac{Q''_1}{Q''_2} = 2.71$$

The ratio of the actual light falling on the 2½-inch objective from the opal glass at the film aperture, to that falling on the 1½-inch objective, at 5½ inches is then less than 2.78 and more than 2.70. Since the distances in the table are the same for objectives of both sizes their average deflection ratio is the same as the ratio of the averages of their product columns. The last line of the table shows this ratio of the average for the three different cell potentials to be in good agreement and to lie within the predicted range. This means that the galvanometer deflection is proportional to the quantity of light entering the cell, regardless of the size of objective used—at least within the range treated in the present paper. Since the light entering the cell is the same as the light delivered to the objective, except for the constant proportion lost at the condenser in front of the cell, the deflection, and so the ordinates of the plates, do truly represent the quantity of light delivered to the objective by the rest of the system. The amount of this light that will be delivered to the screen by an objective of the diameter considered depends only on its reflection and absorption losses, which in turn depend on the type of lens and to a negligible degree only, on its size.

In making plates to determine simply the quantity of light, the 2½-inch dummy objective was inserted and the source was first set at .2-inch square. A value of d_1 near the best value was then chosen and with this d_1 the part of the d_2 — deflection curve in the neighborhood of the maximum was run, the maximum deflection of this curve being noted. The d_1 was then increased by one-quarter of an inch (or in the case of the prismatic condensers, where the d_1 was small, by one-eighth of an inch.) A section of this d_2 deflection curve was run and the maximum noted, and so on until the noted maxima showed a decided falling off for the successive steps. The value of d_1 was then decreased from the original value in steps until the maxima again showed the falling off. The source was then changed to a .3-inch square and the procedure repeated: then to .4-inch, .5-inch, .7-inch, 1.0-inch and finally 2.0 inches on a side. With this last source size d_1 proved to have a great range of values within which there was very little change in the maximum light, although a considerable difference in the range of d_2 for which the light was approximately constant. This plate for the meniscus plano convex condenser is shown in Fig. 3 as an example.

The 2½-inch objective was then replaced by the 1½-inch objective and similar curves made (Fig. 4). In the case of the plano convex condenser it was found necessary to lift the cell potential in steps for sources above .4-inch, in order to avoid the confusion due to the overlapping of so many curves.

Since the maximum light that we can ever get through the

aperture to the objective is that which would fall on it if the entire angle of view through the aperture from every point on the objective were filled with the source, there can be obtained, by removing the condenser entirely and using a source larger than the aperture and very close to it, a deflection on the plate corresponding to what may be called the "Maximum Theoretical Limit" of the condenser. To find this value on each plate a curve was run without condenser, using a source 2.0″ square. For this curve the d_2 represents the distance from the source to the aperture plate. Starting at a low value for large values of d_2, the deflection increases at first approximately as the square of d_2 decreases, but when finally the aperture approaches close to the opal glass the curve flattens out almost parallel to the d_2 axis. We should expect this end of the curve to be a straight line and meet the deflection axis at right angles, but in the plates this was not the case, probably because of the slight falling off of the intensity of the illumination at the edges of the opal glass source, and of its failure to scatter the light uniformly in all directions. This accounts, too, for the failure of the Maximum Theoretical Limit to increase as rapidly as does the objective area. The deflection at a distance of 1½ inches was chosen as an approximate value of the theoretical limit for the size of objective considered. This value, when using a 2½-inch objective, was marked unity on the plates, and the deflection of other points in proportion.

For each of the condensers, a plate was then made having a curve for both sizes of objectives, and each size of source, using that value of d_1 which the previous plates had shown to give the highest maximum. These plates are shown in Figs. 5, 6, 7 and 8 for the meniscus plano convex, double plano convex and two prismatic condensers No. 2 and No. 3. Of these No. 2 is a slightly yellow prismatic in common use and No. 3 a new design made in whiter glass. The slight variations in the values of the maxima of corresponding curves are probably due to differences in the centering of the optical apparatus, as it was found quite difficult to keep rigidly constant positions involving the many freedoms necessary for the great flexibility required. Below is given a summary of the maximum deflections for various source sizes for the condenser systems so far tried.

Source	Objective	Plano Convex	Meniscus	Prismatic No. 2	Prismatic No. 3
.2″	2½	.20	.18	.26	.24
	1½	.12	.12	.17	.16
.3″	2½	.33	.33	.41	.44
	1½	.20	.22	.21	.24
.4″	2½	.48	.46	.47	.52
	1½	.24	.26	.23	.28
.5″	2½	.58	.58	.51	.61
	1½	.27	.28	.25	.30
.7″	2½	.70	.72	.65	.71
	1½	.27	.28	.30	.32
1.0″	2½	.73	.75	.80	.81
	1½	.28	.29	.30	.32
2.0″	2½	.75	.78	.80	.84
	1½	.28	.29	.31	.33

Fig. 9

If we consider the energy necessary to heat a source to a given temperature as approximately proportional to its area, we can plot a curve for each condenser indicating the relation of light delivered to energy expended. Such curves are shown in Fig. 10. It will be seen from these curves that the gain of illumination is slight for sources larger than .5-inch for the 1½-inch objective and .7-inch for the 2½-inch objective as long as any condenser is used. Considering the difference in type between the condensers, the equality of the light supplied the objective is remarkable.

Fig. 11 shows the curves for a half inch source with different values of d_1 when using objectives 1¾ inches, 2 inches and 2¼ inches in diameter, as well as the 2½ inches and 1½ inches in connection with the plano convex condensers. The ordinate .59 was assumed from Fig. 6, and the others measured from this.

As was pointed out in the first paper, a strict comparison of the light coming from different sources or passing through different media is impossible by the use of a photoelectric cell alone, since the sensibility—wave-length curve of the cell and the eye are not the same, and since light measurement in projection means measurement of the effect of the light on the eye. To determine the correction that must be applied to the photoelectric cell readings, due to selective absorption in the condensers, the following method was employed.

After setting up the first three condenser systems in some position of which the ordinate was known in terms of the theoretical limit, ten measurements of the light falling on the objective were taken with an optical photometer and then ten measurements of the theoretical limit. These measurements are shown in Fig. 12. As indicated each set was made with two different potentials on the source lamp (125 and 110 volts), i. e., two colors of opal glass source. The low potentials corresponds to a temperature of about 2650°K and upper to about 2770°K. Since the highest temperature at present used in an incandescent filament is about 3250°K and the arc crater 4000°K, this range of 120° will indicate but roughly what allowance must be made in the comparison of the different condensers by the cell method, though much of the violet light given off by the arc is absorbed by the glass of the lenses.

The fact that the ratio of light transmitted to the theoretical limit is higher with a higher source temperature for the prismatic No. 2 and for the meniscus, would seem to point to an absorption of the long wave lengths and a corresponding greenish tint to the condensers. This was true for the menicus, but the prismatic was yellow, rather than green and should then perhaps not have shown this tendency. The difference is slight in any case.

In the last column are given the corresponding deflections taken from Figs 7, 5 and 6. These were made at a source temperature of about 2680°K. As has been said, prismatic No. 2 had a slightly yellow tinge. This would give it a slightly higher value to the eye than to the photoelectric cell. This is shown in the table. The other two condensers are so nearly alike by the two methods that it would seem unnecessary to use an optical check on the cell at all

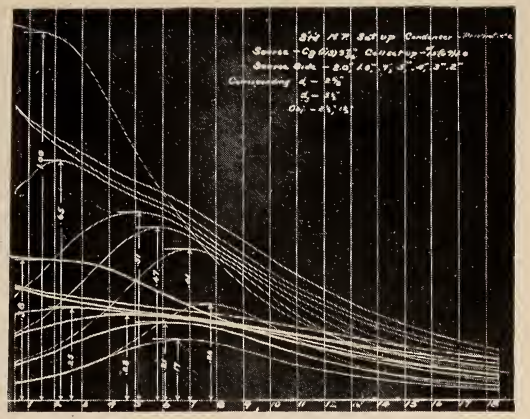


Fig. 7.

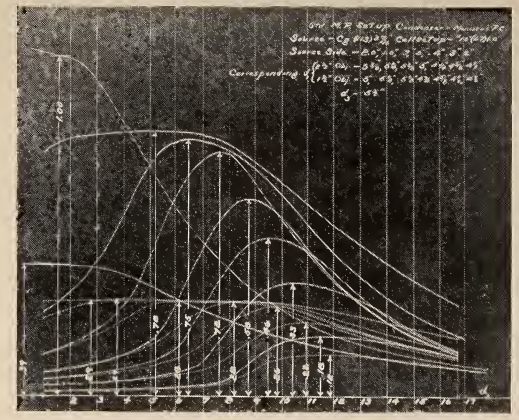


Fig. 5.

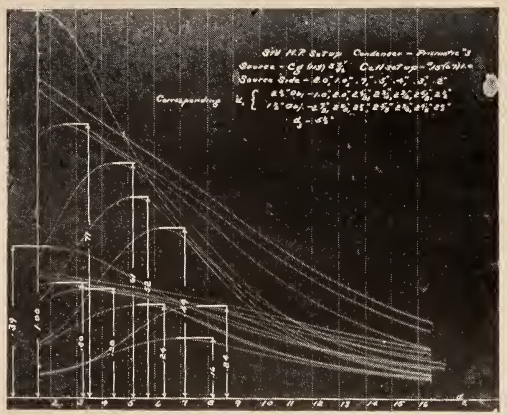


Fig. 8.

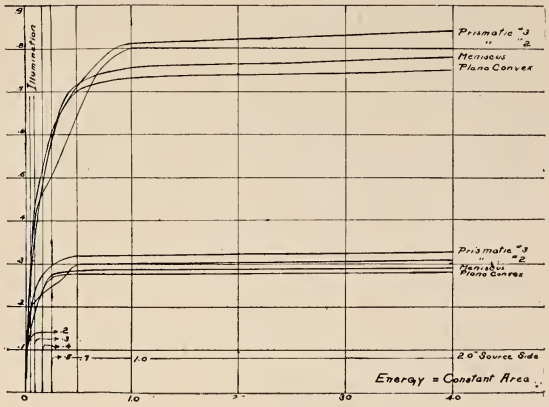


Fig. 10.

as long as the condenser exhibits no yellow color. A caution must be voiced, however, along this line, for color, or lack of color, in glass may be due to absorption in two or more regions of the spectrum, and so may lead to error in the comparison unless an optical check is made in each case. With the condensers used in the present tests, the readings were considered close enough to justify the adoption of those given by the cell as representing the effect on the eye, with a slight reservation in favor of prismatic No. 2.

Fig. 12

COMPARISON OF PHOTO ELECTRIC CELL CURVES WITH PHOTOMETER READINGS.

Source Side	Source Volts	d_1	d_2	Amp.	Photometer Readings					Av.	Light with Cond. Theoretical Limit Photometer	Light with Cond. Theoretical Limit Cell
					Prismatic Condenser No. 2							
½″	125	2⅝	5⅛	.35	1.89	1.96	1.90	1.94	2.0	1.93	.55	
					1 92	1.90	1.96	1.90	1.95			
					Theoretical Limit							
2″	125			.35	3.43	3.75	3.50	3.80	3.40	3.51		
					3.55	3.35	3.50	3.20	3.60			
					Prismatic Condenser No. 2							
½″	110	2⅝	5⅛	.35	1.45	1.15	1.14	1.10	1.19	1.18	.52	.51
					Theoretical Limit							
2″	110			.35	2.35	2.25	2.15	2.15	2.25	2.26		
					2.26	2.45	2.35	2.15	2.30			
					Meniscus Condenser							
½″	125	5	8¾	.35	2.15	2.10	2.20	2.05	2.15	2.15	.602	
					2.05	2.15	2.30	2.20	2.15			
					Theoretical Limit							
2″	125			.35	3.45	3.72	3.50	3.70	3.65	3.57		
					3.10	3.80	3 85	3.60	3.30			
					Meniscus Condenser							
½″	110	5	8¾	.35	1.18	1.30	1.22	1.34	1.24	1.33	.584	.58
					1.32	1.26	1.34	1.27	1.23			
					Theoretical Limit							
2″	110			.35	2.30	2.25	2.35	2.35	2.20	2.28		
					2.15	2.35	2.30	2.20	2.35			
					Plano Convex Condenser							
½″	125	5⅛	8¾	.36	1.79	1.72	1.84	1.79	1.76	1.79	.594	.59
					1.90	1.77	1.77	1.78	1.81			
					Theoretical Limit							
2″	125			.36	2.95	3.15	2.8	3.0	2.8	3.01		
					3.15	3.0	3.1	2.95	3.2			
					Plano Convex Condenser							
½″	110	5⅛	8¾	.36	1.08	1.05	1.07	1.15	1.06			
					1.07	1.05	1.05	1.07	1.05	1.07	.594	.59
					Theoretical Limit							
2″	110			.36	1.78	1.91	1.80	1.72	1.84	1.81		
					1.86	1.80	1.80	1.75	1.80			

Motion-picture projection does not concern itself with the total quantity of light alone. Uniformity of screen illumination is also a factor. Five plates were made as a basis of curves showing uniformity. Fig. 13 shows two families of curves made with a plano convex condenser, one with a 2½-inch and the other with a 1¾-inch dummy objective. Each family consists of curves differing in d_1 as before. The maximum ordinate of the upper family has been assumed as .59 from Fig. 6 and the others calculated from their proportional lengths. Figs 14 and 15 are the same kind of curves made with prismatic No. 2 and prismatic No. 3, although, of course, with different actual values of d_1. These three plates were made with an opal glass source .5-inch on a side which is approximately equivalent in area and uniformity to the crater of a direct-current arc of 110 amperes, and in area to the 900-watt incandescent filament lamp. Figs. 16 and 17 were made with plano convex and prismatic No. 3 condenser respectively, and .3-inch source, equivalent to a 33-ampere arc.

To determine what part of each of the curves could be used

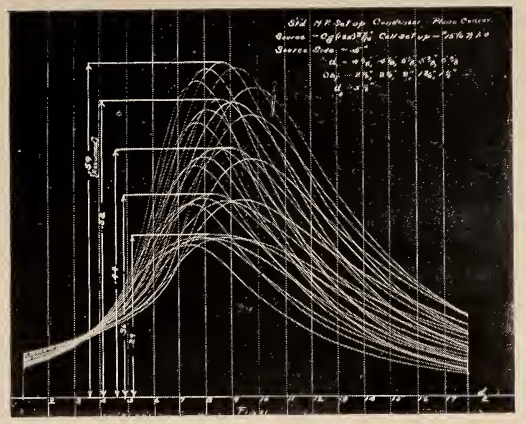


Fig. 11.

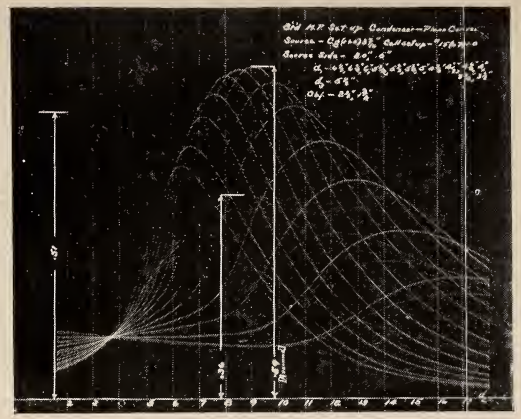


Fig. 13.

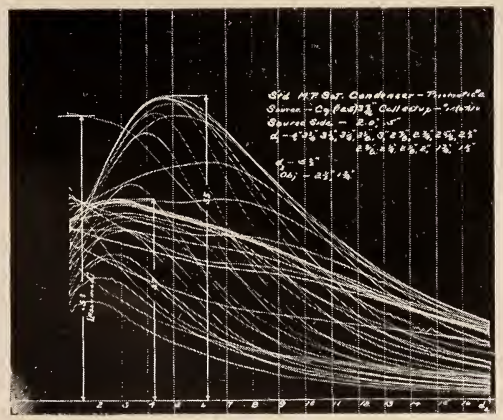


Fig. 14.

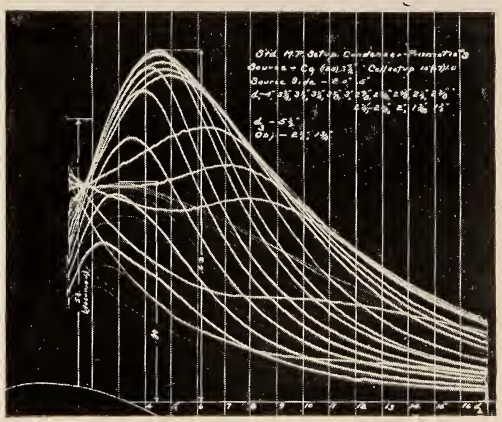


Fig. 15.

in projection without an un-uniformity of illumination on the screen, the dummy objective was replaced by a real objective lens, and the image of the aperture thrown on the screen. The objectives at hand were $2\frac{7}{16}$-inch effective diameter, 5½-inch equivalent focus, and 1½-inch diameter, 4-inch focus. The latter is of about the same speed as a 1¾-inch diameter, 5½-inch focus, and will give approximately the same total illumination curves. It was because this 4-inch equivalent focus lens was the only small diameter lens at hand that the second dummy objective used in the curve was 1¾ inches in diameter, instead of 1½ inches as previously.

With opal glass .3 inch and .5 inch square, and a 900-watt incandescent filament lamp as sources, with each of these objectives and with each of the three condensers, and each of the d_1 used in Figs. 13 to 17, d_{2_i} was varied and the uniformity of illumination of the screen carefully observed. For each arrangement, the range of values of d_2 for which the screen showed the following characteristics was noted:

ILLUMINATION	NOTATION				
1. Uniformity	———	———	———	———	———
2. Dark center	o	o	o	o	o
3. Dark corners	.	.	.	.	.
4. Black corners	—	—	—	—	—
5. Streaks	I	I	I	I	I
6. Image of the Source	II	II	II	II	II

Of these the last two were noticeable only when using the incandescent filament. Of course, these observations involving as they do merely the appearance of uniformity, though not being at all accurate—as shown by the many inconsistencies of the readings of d_2—are nevertheless exactly the kind of observations that affect practical projection.

Tracings were next made from the plates, of representative curves of each source size, condenser and objective combination and the different parts of each curve drawn in the appropriate symbol or symbols, where several kinds of un-uniformity overlapped. Tracings for the 900-watt incandescent filament lamp were made, of course, from the plates taken with a .5/10-inch source, the symbols being determined by observation of the screen as described above. Some of these tracings are shown in Figs. 18-24. The objectives are called 2½-inch and 1¾-inch in these figures, but they were really, as has been pointed out, 2½-inch diameter, 5½-inch focus and 1½-inch diameter, 4-inch focus.

Figs. 18 and 19 show the distribution for different values of d_1 when the plano convex and prismatic No. 3 condensers are used with a .3-inch source. The subscript "a" refers to the 2½-inch objective and "b" to the 1¾-inch objective. Figs. 20 and 21 give the same condensers with a .5″ source. These curves show the gain in uniformity as well as brightness when the larger source is used. Figs. 22 and 23 taken in connection with the last plates show the effect of the coils of the incandescent filament on screen uniformity with the different condensing systems. Fig. 24 shows the same thing using prismatic No. 2.

It is apparent from Figs. 18 to 21 that with sources of uniform

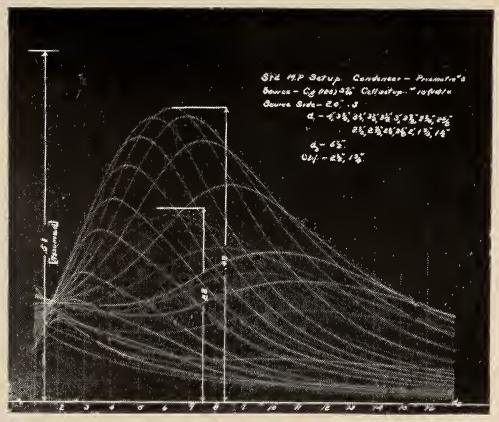


Fig. 16.

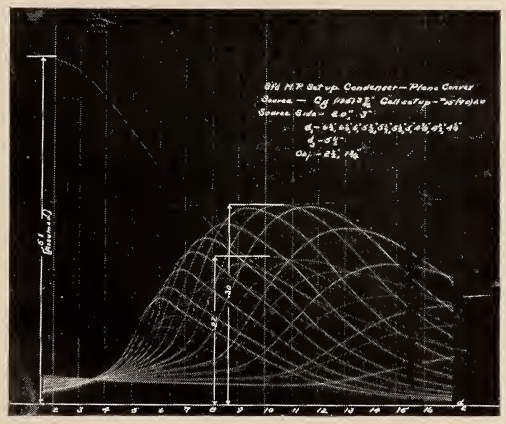


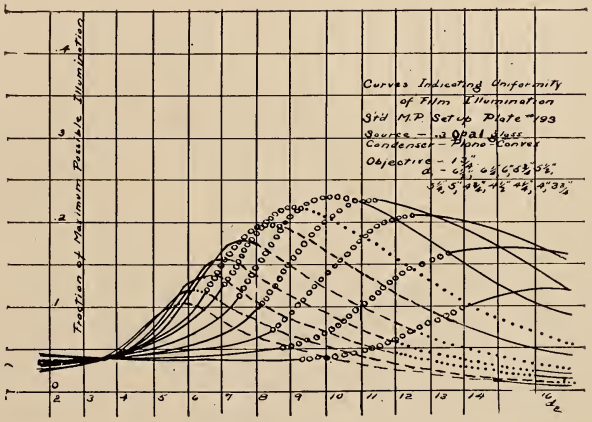
Fig. 17.

brilliancy, such as an arc crater, the value of condenser efficiency in actual projection can be as high as those given in Fig. 9, but from Figs. 22 to 24, it is evident that when using the 900-watt motion-picture lamp, the illumination that can be obtained with a uniform screen is less than the maximum illumination represented by the tops of these curves. Fig. 25 shows the reductions with plano convex and the two prismatic condensers for 2½-inch and 1¾-inch objectives.

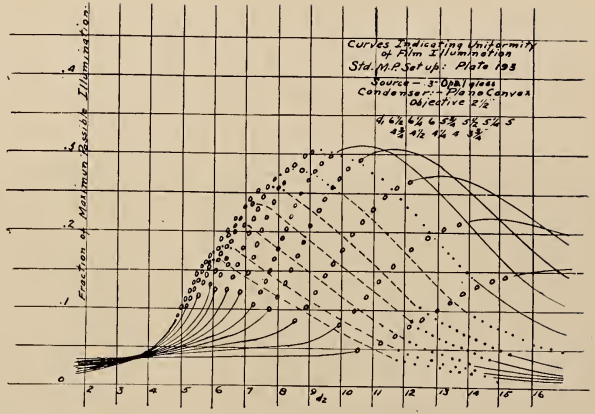
Fig. 25

	Plano Convex		Prismatic No. 2		Prismatic No. 3	
Condenser Objective	2½″	1¾″	2½″	1¾″	2½″	1¾″
Max. Illumination	.59	.37	.56	.35	.61	.38
Max. Uniform Illumination	.28	.30	.45	.11	.58	.38

These figures show the great gain in uniform illumination, with an un-uniform source, made possible by the use of a condenser, such as the prismatic, which does not give a true image. The very low value with prismatic No. 2, when used with a small objective, is



Left
Fig. 18a.



Right
Fig. 18b.

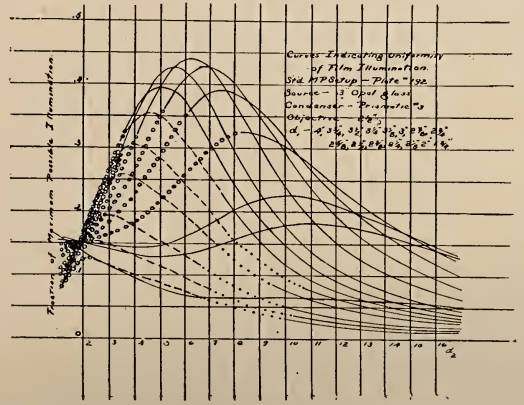


Fig. 19a.

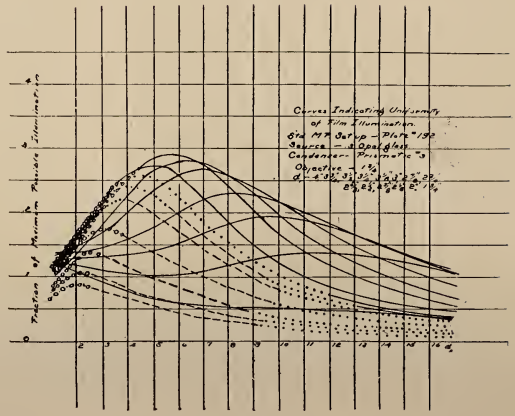


Fig. 19b.

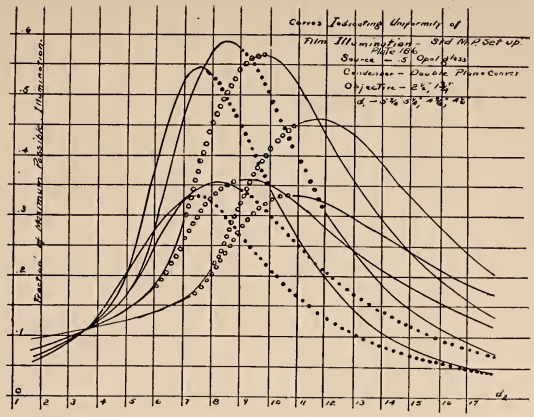


Fig. 20.

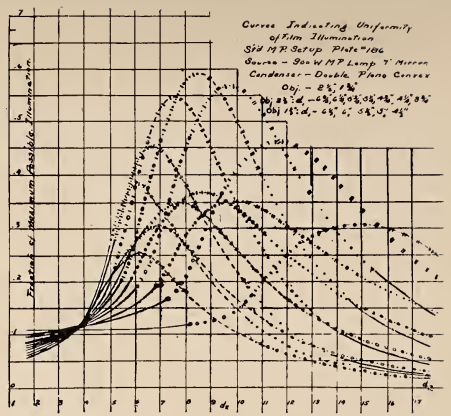


Fig. 22.

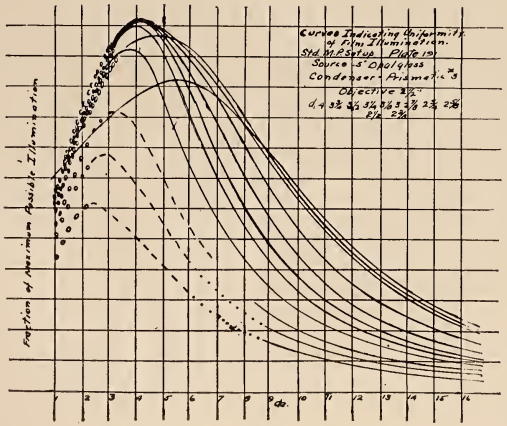


Fig. 21a.

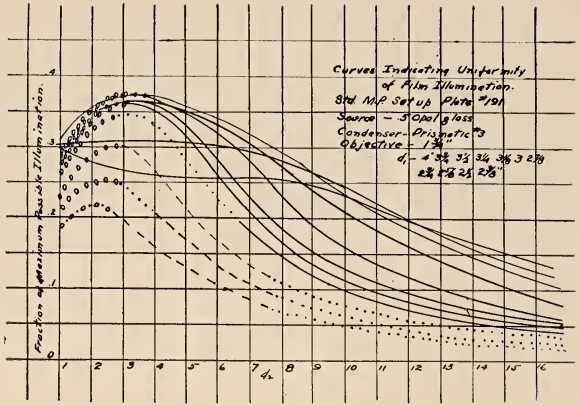


Fig. 21b.

due to the preponderance of light coming through its center, which is a simple lens. Prismatic No. 3 has been designed to break up the filament images more than does No. 2. The result of this is a great extension of the uniform range. It is evident that though the larger objective gives more light in all three cases, it does not, when used with the plano convex condenser, give appreciably more light in the uniform range.

SUMMARY

The results obtained so far may be summarized as follows:

1. The photoelectric cell can be made to give readings closely proportional to the total illumination, as measured by an optical photometer, delivered to an objective of any size, and for any differences of color normally met in practice.

2. There is no material gain in illumination for any of the condenser systems tried, by the use of a source larger than .7-inch on a side for a 2½-inch objective or .5-inch for a 1½-inch objective.

3. There is not more than 10 per cent. difference in the maximum total illumination given by any of the types of condensers when used with a source .4-inch or over.

4. For sources as large as .4-inch with any of the condensers tried, there is delivered to the 2½-inch objective at least twice as much light as to the 1½-inch.

5. Uniformity of illumination accompanies maximum illumination for all the condensers and objectives considered when used with uniform sources having an area as great as .3-inch square. On the other hand, for the 900-watt motion-picture lamp, although the prismatic condenser No. 3, when used with a 1¾-inch objective gives a maximum illumination that is uniform, when used with a 2½-inch objective, the greatest uniform illumination is 6 per cent. below the maximum. The plano convex condenser requires a decrease of 20 per cent. to obtain uniformity with the 1¾-inch objective and over 50 per cent. with the 2½-inch objective, whereas uniform illumination can be obtained with prismatic No. 2 only by a sacrifice of 69 per cent. with 1½-inch objective though with a 2½-inch objective of but 20 per cent.

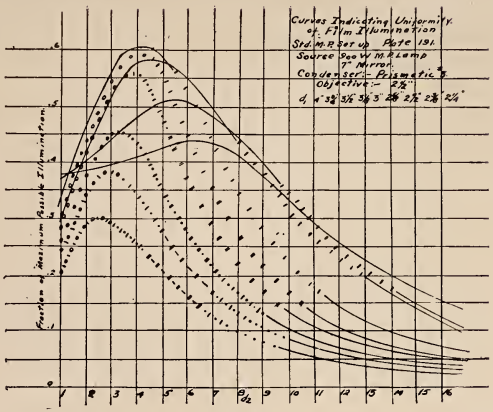


Fig. 23a.

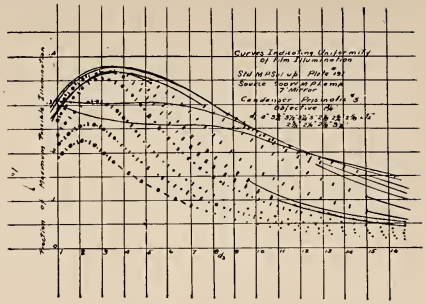


Fig. 23b.

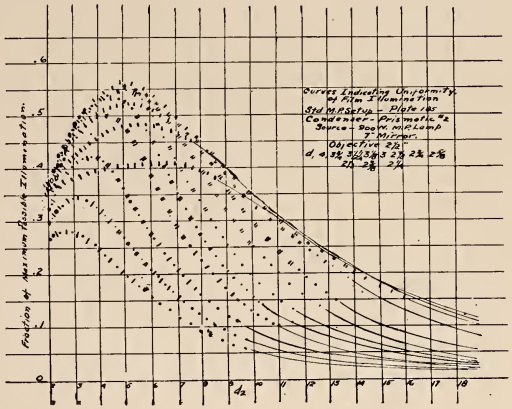


Fig. 24a.

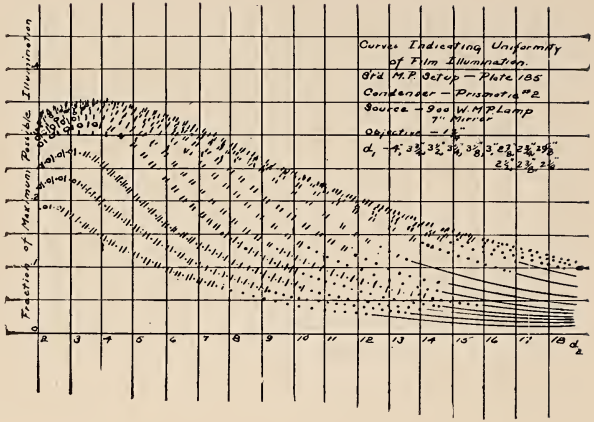


Fig. 24b.

Report of the Optics Committee

Since the last meeting of the society, your Committee on Optics has had three meetings to determine, if possible, the effect on an optience of tint in a motion picture. Unfortunately, due to the wide scattering of the committee, at no meeting have there been more than four members present. In spite of this, however, the committee has at least made a start toward collecting the data required of it. This report then it but a preliminary one showing results already obtained and pointing the way to a large field of most interesting investigation in the future.

In the first place, it was thought color could affect the picture on the screen in five ways. The apparent brightness may be affected. The clearness. The contrast. Then again color may improve the naturalness of the picture. For example, a blue tint for the sea, a red tint for a burning building, etc. The fifth way is in the effect of color on the mood. These last two ways the committee has, for the time being, disregarded as belonging to the psychological rather than the physiological phase of the subject, and so a question for the producer rather than the engineer.

At the first meeting of the committee, March 23rd, a general method of approaching the problem was decided upon. It would seem that screens that would absorb part of the spectrum, when illuminated with white light (i. e., tinted screens) could be assumed to give identical effects on the eye, as white screens illuminated by light from which the same part of the spectrum had been absorbed by some interposed filter. Accordingly, considerations of convenience led to the adoption for the tests at hand of white screens and of white light, from which different colors had been absorbed. The only way of comparing colors accurately was thought to be the observing of a picture in each color thrown simultaneously on the screen side by side. A request was then sent the Eastman Kodak Co. for a number of short lengths from the same film (i. e., all the lengths printed and finished from the same negative film under the same conditions), each length to be dyed different color. These were very kindly furnished the committee. Each length was then fastened in a loop so that it could be run through a machine continuously.

While these films were in the course of preparation, some crude preliminary experiments were made at a meeting on April 13th. These tests consisted in running a loop of untinted film through a machine and observing the effect of interposing a number of tinted gelatine filters (furnished by the Bausch & Lomb Co.) in the light beam in front of the objective. It was found, as had been expected, that it was impossible to remember the characteristics of a previous color well enough to compare it with the color on the screen, except in cases of extreme difference. So extreme did these differences have to be that the committee almost despaired of arriving at any helpful conclusions.

When the tinted films arrived the facilities of the Cinema

Quipment Center in New York were generously put at the disposal of the Committee for the test. Two arc projectors, similar in all respects, were arranged to throw two pictures, side by side, on a single white beaded screen, and the optience (from 5 to 8 in number) sat in the line between the two pictures. Both arcs were maintained, as nearly as possible, at 60 amperes and 50 volts throughout the tests. To each person were given slips of papers having spaces for checking his preference of the two pictures on the screen in respect to brightness, clearness and contrast. With light beams intercepted, the untinted loop of film was put in one machine and a tinted loop in the other. The room lights were turned off and then the two pictures thrown on the screen. It was originally planned for each observer to note his first impression of the relative brightness, clearness and contrast of the two pictures and then after examining the pictures for two minutes, to note again in separate columns his final decision. It was found, however, that it took so long to form any definite opinion that the pictures were run for one-half minute and judged on the final decision alone. After this half-minute run, the light beams were cut off and the room lights turned on in order that the eyes of the optience might regain their original sensitiveness.

A thin metal disc, having holes all over it ¼ inch between centers, and of such a size that just one-half of the disc area was cut away (i. e.,, hole .2 inch in diameter) was placed in the front of the objective throwing the untinted picture. A second test was now made and judged as before. Then a third with a disc having one-quarter of its area cut away (.141 inch holes), and a fourth with one-eighth (.1 inch holes) cut away. These discs, of course, reduced the quantity of light from the untinted film to one-half, one-quarter and one-eighth of its original value respectively, while the tinted picture remained unchanged.

The results of tnese tests are given in the table. Only a decided majority of votes was considered as an indication of difference. It was quite astonishing, however, to find how closely the opinions coincided in the great majority of cases. The colors tried were:

Pale rose, pale carmine, deep red and deep carmine.

Pale amber, pale yellow, pale lemon, lemon and deep amber.

Very pale green, pale blue green, pale olive, grass green and deep green.

Pale blue, blue, deep blue, red blue, very red blue, deep purple and deep violet.

Perhaps the most striking thing shown by the table is that the pale yellow and pale green give the appearance of equal or greater brightness, though, of course, having less energy delivered to the screen by the amount absorbed in the dye on the film. This effect was so marked that in the case of the pale amber, the films and machines were interchanged with results that checked with the previous test. Of equal interest is the fact that the contrast was invariably increased by pale colors, and the clearness as well, with the exception of pale blue, pale blue green, pale olive and pale car-

mine. Deep blue and deep purple reduce apparent contrast. The purple gave a picture on which it was noticeably hard to focus the eyes satisfactorily. Pale carmine was the first tint run and it afterwards developed that some of the judges had not understood the system on this first color, and through an oversight, this was not run again. This probably accounts for its eccentric behavior.

I. Untinted Light Unreduced

			Summary		
Increase	No effect	Decrease	Increase	No effect	Decrease
		Brightness			
Pale	Pale Yellow	All others	1	3	17
Amber	Pale Lemon				
	Very Pale Green				
		Clearness			
{Very red, Blue}	Pale blue	Blue	6	6	9
		Grass green			
Pale rose	Red blue	Deep blue			
		Deep blue green			
Pale amber	Deep carmine	Deep purple			
Pale yellow	Deep amber	Deep violet			
	{Pale blue, green}	Deep red			
Pale lemon					
{Very pale, green}	Pale olive	Pale carmine			
		Lemon			
		Contrast			
All others	Blue	Deep blue			
	Red blue	Deep purple	14	5	2
	Deep violet				
	Deep red				
	Deep blue green				

II. Untinted Light Reduced to ½

			Summary		
Increase	No effect	Decrease	Increase	No effect	Decrease
		Brightness			
Red blue	Pale blue	Very red blue			
Pale carmine	Pale rose	Blue			
Deep red	Deep carmine	Deep blue			
Pale amber	Pale olive	Deep purple			
Pale yellow		Deep violet	9	4	8
Pale lemon		Grass green			
Lemon		Pale blue green			
Deep amber		Deep blue green			
Very pale green					
		Clearness			
All others	Deep violet	Deep blue			
		Deep purple			
		Deep blue green	17	1	3
		Contrast			
	Deep blue	Deep purple	19	1	1

III. Untinted Light Reduced to ¼

			Summary		
Increase	No effect	Decrease	Increase	No effect	Decrease
		Brightness			
All others	Deep blue	Deep purple			
	Pale carmine		17	3	1
	Deep blue green				
		Clearness			
All others	Deep blue	Deep purple			
	Pale carmine		10	2	1
		Contrast			
All others	Pale carmine	Deep purple	19	1	1

IV. Untinted Light Reduced to ⅛

			Summary		
Increase	No effect	Decrease	Increase	No effect	Decrease
		Brightness			
	Pale carmine		20	1	0
		Clearness			
	Pale carmine	Deep purple	19	1	1
		Contrast			
	Pale carmine				

The above results are not complete, as the committee has not yet been able to determine the quantity of light absorbed by the dye, and accordingly the ratio between the actual energy passing through the tinted and untinted films. When this is known, it is expected that the advantage of tints will be still more strongly marked. The committee hopes to have this information by the next meeting of the society.

TRANSACTIONS

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

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Number Eleven

MEETING OF OCTOBER 11, 12, 13, 14, 1920

DAYTON, OHIO

TRANSACTIONS

OF THE

SOCIETY OF MOTION PICTURE ENGINEERS

Number Eleven

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DAYTON, OHIO

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RESULT OF ANNUAL ELECTION
OCTOBER, 1920

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EXTRACTS FROM BY-LAWS

Membership in the Society of Motion Picture Engineers stands for unselfish service to the Industry. Applications for membership are by invitation and endorsement. All checks should be made payable to the Society of Motion Picture Engineers.

All receipts are expended directly to promote the objects of the Society and the interests of its members. There are no salaries or emoluments of any kind.

The following are extracts from the By-Laws:

The objects of the Society are: The advancement in the theory and practice of motion-picture engineering and the allied arts and sciences, the standardization of the mechanisms and practices employed therein and the maintenance of a high professional standing among its members.

Qualifications

Active Member—An Active member shall not be less than 25 years of age and shall be:

(a) A motion picture engineer by profession. He shall have been in the practice of his profession for a period of at least three years and shall have taken responsibility for the design, installation or operation of systems or apparatus pertaining to the motion picture industry.

(b) A person regularly employed in motion picture or closely allied work, who by his inventions or proficiency in motion picture science or as an executive of a motion picture enterprise of large scope, has attained a recognized standing in the motion picture art. In the case of such an executive, the applicant must be qualified to take full charge of the broader features of motion picture engineering involved in the work under his direction.

Associate Member—An Associate member shall not be less than 21 years of age and shall be:

A person who is interested in or connected with the study of motion picture technical problems or the application of the same.

Any person of good character may be a member in any or all classes to which he is eligible.

Prospective members shall be proposed in writing by at least one member in good standing, and may be elected only by the unanimous vote of the Board of Governors.

All applications for membership or transfers in class shall be made on blank forms provided for the purpose, and shall be accompanied by the required fee.

Entrance Fees and Dues

The entrance and transfer fees, payable on admission to the Society, or upon transfer, are as follows: Admission to grade of Active member, $35.00; admission to grade of Associate member, $10.00.

The transfer fee from Associate grade is the difference between the admission fee, or $25.00.

The annual dues are as follows: For Active members, $20.00; for Associate members, $10.00.

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Akeley Camera, Inc.,
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St. Marys, Pa.

Nelson, Otto,
Dales & Hills,
Dayton, Ohio.

Nixon, Ivan L.,
Bausch & Lomb Optical Co.,
Rochester, N. Y.

Ohmer, W. I.,
Record'g & Comput'g Mach. Co.,
Dayton, Ohio.

Perkins, E. G.,
704 Dollar Bank Bldg.,
Youngstown, Ohio.

Rohr, C. A.,
General Electric Co.,
120 Broadway, N. Y. City.

Stevenson, A. R., Jr.,
General Electric Co.,
Schenectady, N. Y.

LISTS OF VARIOUS COMMITTEES—1920-1921
Society of Motion Picture Engineers

Electric Devices Committee

W. F. Little, *Chairman*

R. L. Lee
A. R. Dennington
J. H. Hertner
W. C. Kunzman
Max Meyer
J. S. Speer
E. L. Bragdon
C. A. B. Halvorson
A. D. Cameron
J. R. Manheimer
H. F. O'Brien
P. R. Bassett
W. C. Hubbard

Projection Machines Committee

W. C. Smith, *Chairman*

A. C. Roebuck
W. B. Cook
F. H. Richardson
C. F. Jenkins
E. M. Porter
A. F. Victor
Herman Casler
J. R. Cameron
B. R. Proctor
F. Morrison

Papers Committee

L. C. Porter, *Chairman*

R. P. Burrows
H. C. MacNary
E. L. Bragdon

Safety Committee

A. F. Victor, *Chairman*

J. C. Moulton
G. A. Blair

A. D. Cameron, *Chairman*

Frank Rembusch
J. S. Speer

Optics Committee

W. E. Story, *Chairman*

Hermann Kellner
E. L. Bragdon
R. S. Burnap
L. A. Jones
W. V. D. Kelley
J. C. Kroesen
W. F. Little
F. H. Richardson
H. P. Gage
H. M. R. Glover

Nomenclature Committee

C. F. Jenkins, *Chairman*

Carl Gregory
Max Mayer
H. P. Gage
W. E. Storey
W. F. Little
Major R. Grierson
H. F. O'Brien

Studios Committee

E. F. Murphy
W. R. Rothacker
W. R. Mott
W. C. Hubbard
M. W. Palmer
H. F. O'Brien
Walter Quinlan

Educational Committee

A. R. Dennington, *Chairman*

F. H. Richardson
G. A. Blair
A. F. Victor
C. F. Jenkins
E. K. Gallett
W. B. Cook
J. R. Cameron
W. F. Braun
C. A. B. Halvorson
L. E. Davidson
C. E. Egeler
Carl Gregory

Publications Committee

W. B. Cook, *Chairman*

E. L. Bragdon
H. C. MacNary
J. C. Kroesen

Advertising Committee

R. P. Burrows, *Chairman*

J. A. Summers
W. C. Kunzman

Membership Committee

A. C. Roebuck, *Chairman*

C. F. Jenkins
E. K. Gillett
H. F. O'Brien
R. L. Lee
W. C. Kunzman
G. A. Blair
G. F. Perkins
H. H. Cudmore
W. C. Hubbard
F. H. Richardson
W. C. Smith
R. Grierson

Cameras and Perforations Committee

W. B. Cook, *Chairman*

Carl Gregory
Carl Akeley
A. S. Howell
C. F. Jenkins

Reciprocal Relations

R. P. Burrows, *Chairman*

Herman Kellner
W. B. Cook

PRESIDENT'S ADDRESS

ANY doubts as to the success of the Society of Motion Picture Engineers has long since been dispelled. The period since the organization of our Society has been a trying one. Dark clouds have loomed on the horizon of our vision, but these have disappeared and our future now looks exceedingly bright. We have just completed our fourth year and we look optimistically to the future.

If you will permit me, I shall say a few words with reference to our membership. The Society began in the Fall of 1916 with approximately 25 members. Of this number, 18 are still on the roll and in good standing. Since then, our membership has increased until it now has a total of 78 members, notwithstanding quite a number of members have dropped out through resignation or other causes.

You, by your action at the Montreal meeting, authorized the formation of an Associate Membership classification. This is going to be a considerable help to the Society in furthering its important work. We must be judicious, however, in increasing our membership and see that only those fully entitled to membership are enrolled.

Closely related to the matter of membership is the question of attendance at our meetings. In order to be a useful member, you should regularly attend the meetings. A careful analysis shows that a little group of faithful members attend regularly, but the greater number attend only irregularly or not at all. We should aim to have a 100% attendance at each meeting. It is the endeavor to make the meetings as instructive and interesting as possible and to this end, your officials have been both active and solicitous.

I have frequently and consistently pointed out at previous meetings, the fact that the backbone of our Society should be and is, the result of the work of our Standing Committees. Some of our Committees have done commendable work, others have only worked half-heartedly, while others have merely reported progress. In an industry such as the motion picture industry, there are so many developments and changes, that without question, each Committee should have a full and detailed report, at least once a year. The Society will forge ahead only in proportion to the constructive activities of its various Committees.

The program for this meeting is certainly attractive. The Committee on Arrangements has been untiring in its efforts to make this the best meeting which we have ever held and I am sure that these efforts will be effective. Unquestionably, each of you will leave Dayton with the thought that Dayton is a most hospitable city, that we have had a splendid meeting and that it is not a small honor to be a member of the Society of Motion Picture Engineers.

At this time, I desire to express the appreciation of the Society to those who have made our success possible. This includes, espe-

cially, the officers who willingly served without any compensation whatever, as well as the members of the Committee on Papers and Committee on Publication. It is, by no means, an easy matter to formulate a program. The Committee on Papers has to keep continually after the authors on the matter of preparing papers and, further, it has to see that all promises given are kept. After the papers have been accepted and presented, there is considerable work by the Committee on Papers and Committee on Publication in collecting illustrations, having cuts made, reading of proofs, and arranging for the final printing. A careful analysis of the proceedings of our Montreal meeting, a book of 105 pages, should indicate to you, in a measure, the ground that these Committees have had to cover. Let us show our appreciation of their efforts. The members and others who prepare papers for our program should also receive our appreciation. The preparation of these papers is not a matter of days: it means the presentation of facts, gathered from a fund of data and experience, so grouped as to become easily understood.

Your Board of Governors has regularly met once and sometimes oftener between stated meetings, for the purpose of carrying on and planning the Society's business.

At this, the close of my administration as your President, I want to, personally, thank the officers and members of the Society for the loyal and unselfish support with which I have been encouraged and sustained. Each of you has contributed his part to any efficiency I may have displayed, and as to my short comings, I trust you may overlook them—except as they may serve as danger signals to my successor—recalling only those things in which I may have proved constructive and helpful in leadership.

As we have such an excellent program ahead of us for the next four days I will not burden you further. The meeting is now yours.

H. A. Campe, *President.*

Extracts from

MINUTES OF THE FIFTH ANNUAL MEETING

of the

SOCIETY OF MOTION PICTURE ENGINEERS

Held at the

MIAMI HOTEL, DAYTON, OHIO

October 11, 12, 13, 14, 1920

Monday Morning, October 11th, 1920.

Minutes of the meeting of the Board of Governors, held in New York City on July 19, 1920, and Dayton, October 10, 1920, were read by the Secretary, and approved.

The following new members were elected, and the names read by the Secretary:

Mr. M. Burnays Johnson
Mr. Preston R. Bassett
Mr. Joe Hornstein
Mr. Ivan L. Nixon
Mr. H. A. R. Dutton
Mr. Francis J. McGinnis
Mr. I. V. Hochstetter
Mr. E. G. Perkins

The question of price to be established on the Transactions printed by the Society was brought up and an animated discussion followed.

After careful consideration the following motion was made, seconded and carried.

Motion: That the Transactions up to, but not including, the Pittsburgh meeting be sold as formerly, at $.25 each, and that the price thereafter be $1 each.

The Secretary was instructed to secure prices on binding the four Transactions consisting of the Philadelphia, Pittsburgh, Montreal and Dayton meetings, and that he notify all members of such cost, and have bound up a number of copies, if à sufficient call for them was received.

Luncheon was held at the Engineers' Club, during which the Hon. J. M. Switzer, Mayor of Dayton, welcomed the members to the City, and to which response was made by Past President, Mr. C. F. Jenkins.

Election of Officers.

Report by the nominating committee was read by W. B. Cook, Chairman.

The following officers were elected by written ballot:

President .....H. A. Campe
Vice-President .....Robert P. Burrows
Secretary .....A. F. Victor
Treasurer .....W. E. Smith
Board of Governors..W. B. Cook, L. C. Porter

The election of officers was followed by a paper "History of Motion Pictures," by Mr. C. F. Jenkins.

Mr. A. F. Victor desired to know whether Dr. Goodwin or Carbutt was the real inventor of celluloid.

Both Mr. Jenkins and Mr. Blair stated that Dr. Goodwin was undoubtedly the real inventor.

Report of the Safety Committee was read by Mr. A. F. Victor. Chairman.

Mr. Carl Gregory being absent and his paper not being available, the President requested that Dr. Kellner present his report.

Demonstration and Discussion by Optics Committee.

A discussion followed the report in which Dr. W. E. Storey, Mr. H. P. Gage, Mr. F. W. Little, Mr. I. V. Hochstetter, and Dr. Herman Kellner participated.

Report of Committee on Cameras by Mr. Willard B. Cook, Chairman.

Mr. Cook reported that a new book on "Condensed Course in Motion Picture Photography" had recently been written by Mr. Carl Gregory, a member of the Committee on Cameras, and was now available.

Report from Membership Committee, Mr. A. C. Roebuck, Chairman.

After the report had been read the committee was complimented by the chairman for its splendid activities and the good work whereby the Society had been brought to a membership of over one hundred.

Report from Committee on Advertising, presented by Mr. R. P. Burrows, Chairman.

It was moved, seconded and carried that the first resolution embodied in the report of Mr. Burrow be accepted.

It was moved, seconded and carried that the second resolution embodied in the report of Mr. Burrows be accepted.

A paper was then presented by Mr. G. A. Blair on "Reducing Fire Hazards in Film Exchanges."

Discussion.

Mr. Blair added, after reading his paper, that the Eastman Kodak Company was now extending its work to the actual projection rooms and attempting to educate the projectionists of the country as to the hazards of the material handled by them.

Mr. Campe said that the paper clearly showed the cooperative efforts between many factions to bring about safety.

Mr. Manheimer asked for further details regarding the Kansas City fire referred to in Mr. Blair's paper.

Mr. Blair stated that he was certain that if the fire extinguishers had been installed at the time the fire occurred, they would have easily placed the fire under control, but said that unfortunately the automattic sprinkler system was under construction and not ready to operate at the time of the fire.

Mr. Bernays Johnson said that he had been present during one of the lectures given by the Eastman Kodak Company to Projectionists, but had failed to obtain specific information as to proper methods whereby film fires might be extinguished.

Mr. Blair replied that while he was not in the fire extinguisher business, he considered that water was the best medium for the purpose and that it served to put out fires chiefly due to its cooling action.

Mr. Johnson desired to know whether film was explosive.

Mr. Blair said that it was not explosive if in the open, but only confined in places where the correct mixture of air might be the means of causing an explosion.

Mr. Jenkins desired to know whether the connecting of the upper magazine with the open air would prevent explosions, and also desired to know whether Mr. Blair would recommend the sprinkler system in projection rooms.

Mr. Blair said that he would recommend sprinkler systems in all projection rooms.

Mr. Smith said that his experience had convinced him that most fires occurring in projection booths were due to lack of knowledge on the part of the projectionists. He also stated that if the fire valves in the magazine were kept clean, and, if the projectionist, when a fire occurred to the exposed film, would merely step back from the machine and allow the fire to burn itself out, the safety devices of the projector would automatically smother the fire and no damage would occur.

Mr. Johnson called attention to the possibility of pieces of burning film being dragged through the valves and in their turn setting fire to the reels within the magazines. He again stated that what the projectionists wanted to know is what to do in the case of a fire, and said that he considered they did all they could to keep from having one, but that it would be of advantage if they are instructed how to stop a fire after it had once started.

Mr. Manheimer said that from his experience he was certain that water was the superior medium whereby to put out film fires.

Mr. F. J. McGinnis related a case in which the fire had jumped into the magazine after having ignited some film collected around the top sprocket. He said the projectionist was experienced, but had never had a film fire before, and foolishly opened the upper magazine. The film, composed of a two thousand foot reel, was burning briskly on the floor, and the projectionist seemed unable to

think of something to do, but he (McGinnis) put out the fire very quickly by the aid of a fire extinguisher, and therefore felt certain that if a fire extinguisher was properly used it would serve to put out film fires.

Mr. Smith stated that he knew of the fire in question; that the film was imperfect and that sprocket backed the film up against the magazines, and that no serious fire would have occurred if the magazine door had been left closed.

Mr. C. J. Lang added to the previous remarks the statement that in the fire in question there was about nine inches of film leading from the aperture to the magazine which did not ignite. This proved to be quite a mystery and a number of suggestions were made as to how this had proved possible.

Mr. Campe now called upon Mr. Lee to address the members.

Mr. Lee, after expressing his gratification over the fact that so many members had come to Dayton to attend the meeting, asked that the Society make itself at home while visiting there and said that the Engineers' Club and everything within its walls were at their disposal. He further said that members should not fail to hear Mr. Kettering's address to be made during the dinner scheduled at 6.15 in the evening.

Dinner was given at the Engineers' Club during which the members were addressed by Mr. C. F. Kettering, Chief Engineer of the General Motors Corporation.

His address was a memorable event to the Society, and the Secretary cannot avoid putting in these minutes his own and his fellow members' expression of appreciation.

Tuesday Morning, October 12th, 1920.

Meeting was called to order at 10 A. M.

Telegrams from absent members were read by the Secretary.

A telegraphic invitation from Mr. C. W. Detz, Chairman, Invitation Committee, of Managers and Projectionists, to attend a banquet held at Hamilton, Ohio, in honor of Mr. Richardson, was received and read by the Secretary.

The Secretary was instructed to reply by telegraph and express the Society's appreciation for the courtesy shown.

A paper and discussion, "Power Plant and Electrical Distribution Equipment of New Eastern Studios and Laboratories of the Famous Players-Lasky and Fox Film Corporations," presented by Mr. J. R. Manheimer.

A discussion followed the reading of Mr. Manheimer's paper.

Mr. Burrows, acting chairman during Mr. Campe's absence, said that it was the first paper of the kind presented and felt certain that the paper warranted discussion.

Mr. Richardson desired to know if the bus-bars recommended by Mr. Manheimer in his paper would not deteriorate if overloaded.

Mr. Manheimer explained a system of installing additional units in cases of necessity for greater carrying capacity, and also stated that the bus-bars were vastly superior to cables due to the fact that

they would stand a tremendous overload without causing any trouble even if the overload was such as to render the bus-bars red hot.

Mr. O'Brien said that there appeared to be no protection for each individual bus-bar at the point where it left the main switch. He asked the capacity of individual remote control switches and whether means to take care of expansion and contraction had been taken care of.

Mr. Manheimer said that expansion and contraction of bus-bars, both lateral and vertical had been provided for.

Mr. MacNary called attention to the possibility of different directors using different quantities of light at their work, rendering impossible the acceptance of calculation based upon candle foot illumination in studios. He also called attention to the high cost of installing the system advocated.

Mr. Manheimer agreed that the criticism made by Mr. O'Brien as to the expense of overhead systems was correct, but that the overhead structure was also usable for the fastening of scenery, etc., and therefore had additional advantages making up for the high cost.

Mr. Hubbard said that if future progress would be based upon developments made in the past two years in overhead systems, we may expect some wonderful progress during the next few years.

Mr. Campe informed us that greater advance had been made in studio lighting than any other branch of the industry during the same period of time.

Mr. Manheimer summed up the arguments advanced, and further discussion was referred to the Papers Committee.

Report from Committee on Publications presented by Mr. Bragdon.

Mr. Jenkins suggested that hereafter the lists of committee members be printed in the Transactions.

Mr. Smith suggested that the names and addresses of all members be printed in the Transactions.

This matter was put to a vote and was seconded and carried and the work was referred to the publication committee for action.

Report by Papers Committee presented by Mr. L. C. Porter, Chairman.

The methods advocated by Mr. Porter met with favor and a motion was made, seconded and carried that all of the recommendations offered in the report be accepted and acted upon.

Mr. Porter asked for suggestions from members which might help in obtaining suggestions for papers.

Mr. Jenkins recommended that a paper on the actual making of pictures in studios be prepared.

Mr. McGinnis said that a paper on correct screen angle and the overcoming of Keystone effects was needed.

Treasurer's Report presented by Mr. Will C. Smith.

Report of Auditing Committee presented by Mr. Kunzman.

Report of Nomenclature Committee, Mr. C. F. Jenkins, Chairman.

Mr. Jenkins stated that no report would be presented at this time, owing to the fact that no new developments had occurred.

Mr. Richardson requested a discussion on the standards as published in the Montreal Transactions.

This suggestion was put to vote and it was decided to discuss the matter.

Mr. Richardson called attention to a number of errors and terms in the nomenclature list as published in the Montreal Transactions. He claimed that as printed the terms employed were entirely at variance with established usage by him and other writers.

Mr. Perkins suggested that the list for nomenclature be referred to some new committee for correction.

Mr. Jenkins stated that no terms had been adopted without authorities first having been consulted in the matter, and he thought that the difference of opinion between Mr. Richardson and himself might be due to the fact that one thing may sometimes be called by two different names.

Dr. Kellner desired to know when such a word as optience should be used. He wanted to know when an audience ceased to be an audience and when it commenced to be an optience. Since there would be both music and pictures he had some difficulty in deciding whether he was one or the other.

Mr. Porter explaining how it came about that the cut of the standard theatre film did not appear in the Montreal transactions. It was due to an oversight.

Mr. O'Brien suggested that a committee be appointed at this meeting to take action on the subject.

Mr. Victor made a motion that a committee be appointed to separate the list of nomenclature into its different branches, and that these lists be referred to the committees dealing with that particular subject and then referred back to the nomenclature committee.

The motion was seconded and unanimously carried.

Mr. L. C. Porter desired to make the following amendment to the motion made by Mr. Victor; that any terms, standards, or recommendations proposed by the nomenclature committee be submitted to the Society as a whole at the next convention for consideration, and that final decision be delayed until the next succeeding convention, at which time an approval or rejection by the entire body shall be made.

This amendment was seconded and carried.

Report of Committee on Progress presented by Mr. Dennington, Chairman.

Meeting was called to order at 10.30 Wednesday, October 13, by President Campe, at the N. C. R. Schoolhouse.

Paper by Mr. P. R. Bassett "The High Power Arc in Sperry Automatic Projector" was presented.

After the reading of the paper Mr. Campe announced that Mr. Patterson of The National Cash Register Company would address the members.

A discussion followed the reading of the paper participated in by Mr. B. M. Johnson, Mr. P. R. Bassett, Mr. C. A. B. Halvorson, Dr. Mott, Dr. W. E. Storey, Mr. C. F. Jenkins and Mr. W. E. Kunzman.

Mr. Farley in charge of the lecture department of the National Cash Register Company, addressed the members and explained the multitudinous use of motion pictures in connection with the sale of cash registers.

Slides and pictures were shown and diagrams were traced upon ground glass and projected. The address proved extremely interesting and gave the members an idea of the commercial application of pictures as employed in the work of the N. C. R.

A paper was presented by Mr. F. W. Hockstetter entitled "A New Process of Taking Motion Pictures on Opaque Paper Film" and "Method of Illumination Excluding Thermal Rays."

Mr. Hockstetter announced that he was unable to give a demonstration but those interested should visit his laboratories and see the apparatus referred to in operation.

Mr. Manheimer desired to know the capacity of the magazines in connection with the camera spoken of in Mr. Hockstetter's paper.

Mr. Hockstetter said that the camera would be able to take from one to two hundred feet and the projector from two hundred to five hundred feet.

Mr. Hockstetter did not offer substantial proof of his statements but said that he would be able to do so at a later date when his patent would permit him to do so.

Many members expressed admiration for the work while others were skeptical as to the correct data and questioned the possibility of excluding thermal rays by the methods advanced.

Report of Optics Committee.

"Effect of Color on Motion Pictures" and "Absorption and Reflection Losses in Motion Picture Objectives," presented by Dr. Storey.

Mr. Victor desired to know whether, in Dr. Storey's opinion, the variation of opinions was not based upon color blindness frequently encountered in the eyes of people.

Dr. Storey did not think that the variations of opinion were due to color blindness.

Mr. Porter said that owing to the difficulty of determining the effect on different people it would be impossible to establish a standard for practical purposes.

He further said that, in his estimation, the work of the Optics Committee in dealing with the subject had been carried as far as possible; that the data so far obtained should be printed in the

Transactions and be carried on to a further point at a more convenient time.

Mr. Roebuck expressed his opinion that the two images were too widely separated to give the best opportunity for observation.

Mr. Campe stated that we all realized the splendid work done by the Optics Committee, and that the work was appreciated.

The balance of the session was devoted to a trip through the plant of the National Cash Register Company, which included a luncheon at the N. C. R. Officers' Club Dining Room.

The trip through the National Cash Register factory was followed by a trip to Morain City, the location of Research Laboratories of the General Motors Corporation.

A banquet was given at the Engineers' Club in the evening at 6.30.

During the banquet an address by Col. Deeds proved one of the events of the Society's visit in Dayton.

Col. Deeds related some very interesting incidents from his trips through the battle fields of Europe.

His sympathetic attitude toward the efforts of the engineers today awakened a responsive chord and gave a great deal of encouragement and inspiration to us all.

Thursday, October 14th, 1920.

Meeting called to order by the President at 10 A. M.

Mr. Beusch of the N. C. R. expressed his gratification over the selection by the S. M. P. E. in coming to Dayton, and, on behalf of Mr. Patterson, welcomed us. He expressed Mr. Patterson's great regret in not being able to personally greet us, as he had hoped to do.

A paper "Portable Generating Equipment" was presented by Mr. F. O'Brien.

Discussion followed Mr. O'Brien's paper, during which Mr. Hertner desired to know if the type of carburetor mentioned in Mr. O'Brien's paper employed heavy oil or gasoline.

Mr. O'Brien said that both could be used but that on the coast gasoline was used exclusively, chiefly on account of the expense of the apparatus, gasoline being less damaging to the machines.

Report of Electrical Devices Committee.

Read by Mr. Roebuck during the absence of Mr. Wible, Chairman.

Report of the Projection Machine Committee, presented by Mr. W. C. Smith, Chairman.

Report of the Correspondence Course Committee, presented by A. R. Dennington.

Mr. Victor said that in his opinion the task was beyond the Society, both financially and otherwise and suggested that the matter be definitely dropped.

Mr. Porter remarked that credit for the preparation of the report was due to Mr. Dennington.

Mr. McGinnis cited an attempt made by another organization of which he was a member to establish a correspondence course. He said that he did not question the ability of our Society to produce perfect projectionists by means of correspondence, but called attention to the fact that local requirements where in some cases an apprentice was compelled to put in six months actual work before permitted to operate a projector, would work against the scheme. He said that he agreed with Mr. Victor that the matter be dropped.

Mr. Burrows said that it had been hoped at the time the plan for a correspondence course was proposed, that we would be able to be of assistance to the projectionists, but if, as appeared to be the case, the projectionists would be narrow-minded enough to be antagonistic to the scheme, and if, in addition, the plan was financially impractical, he offered as an alternative that the Society make an offer of assistance to some existing correspondence schools, for instance, the one operated in Scranton.

Mr. Bragdon suggested that by increasing the edition from a suggested 5,000 to 10,000 the cost per copy would be lowered and wondered if this would prove a way out of the difficulty.

Mr. Jenkins stated that he considered the remarks made had very well covered the subject and considered that the difficulties confronting the Society in carrying out its plans were such as to prevent the undertaking of the work.

Mr. Porter, in order to refresh our memory of the recommendation made at the Montreal meeting, read it and said that it might not be practical of the Society to handle the financial end, but that some way might be devised in which our technical knowledge might be at the disposal of the projectionists.

Mr. Cameron said that two correspondence schools already had courses for projectionists.

Mr. Perkins mentioned that in conversation with a member of the La Salle Institute he (the member) had expressed as his opinion that the Institute would be glad to handle the work if the Society would sponsor the matter.

It was moved, seconded and carried that the report be referred back to the Special Committee for further consideration.

Paper on "Characteristics of Motion Picture Screens," by Mr. L. A. Jones.

A discussion followed Mr. Jones' paper.

Mr. Egeler said that the work done by his organization checked very well with Mr. Jones' data. He said that his observation had been that the Keystone effect and placing of screens also called for vertical, as well as horizontal consideration. He asked if Mr. Jones had considered the vertical problem.

Mr. Jones replied that the examination of screens made by him had considered both vertical as well as horizontal questions.

Mr. Victor said that the paper was a "peach" and that here

possible to formulate data whereby screens of given numbers could be obtained for theatres having definite angle requirements.

Mr. Smith stated that Mr. Victor had expressed exactly what was in his mind.

Mr. Rembusch said that he was very much interested in Mr. Jones' paper. He stated that the first mirror screens were manufactured by him and were made for narrow theatres, but that the same screen, if placed at the proper distance from the front rows, would serve for wide theatres. He wanted to know if Mr. Jones had considered the colored screens. He said that a white screen was preferable on account of giving correct color values to tinted and toned films. He gave a description of the effect of various mirror screens and methods of coating surface of such to cause diffusion in making mirror screens practical for wide angle observation.

Mr. Porter wanted to know if the figure obtained from flat screens could also be applied to the concave type.

Mr. Jones said that color had not been considered in his observation. He said that he personally preferred a tinted screen and hoped to obtain data on such screens at a later date. He recommended that the Society decide upon a definite measure of screen illumination, or, at least, a definite limit beyond which we should not go.

It was moved, seconded and unanimously carried that a vote of thanks be given to the following Dayton organizations for the courtesy extended to the S. M. P. E. during its visit as well as the encouragement and inspiration given to our work while in that city:

Delco Light Company,
Delco Company,
National Cash Register Company,
General Motors Corporation,
Engineers' Club of Dayton,
Miami Hotel, Mr. Smith and their assistants, and the Secretary be instructed to write a letter of appreciation to each organization.

The President now requested that places for our next meeting be suggested.

It was moved, seconded and carried that the next meeting place be selected by means of a ballot.

While the ballot was being taken a report from the Sustaining Membership Committee was rendered by Mr. Cudmore, Chairman.

Mr. Cudmore said that a number of letters had been sent out and that plenty of replies had been received, but that no practical result had been attained. He felt that the method tried would not produce the personnel desired, and that it required the efforts of the entire Society to obtain such members as are truly desirable. He made the suggestion that every member make it his business to pick out the men wanted and send the names to him (Mr. Cudmore) or someone else acquainted with the person suggested. A personal interview should then be arranged with the prospect. He placed the matter before the Board of Governors for their consideration and

said that he felt certain that financial support could be obtained by the method suggested. An additional suggestion made by Mr. Cudmore was that a chapter of the Society be formed in California.

Mr. Campe considered Mr. Cudmore's remarks well made and said the suggestions would be considered by the Board of Governors.

Upon counting the ballots it was found that Washington had been selected with Los Angeles a close second.

The meeting was therefore adjourned until the next convention to be held in Washington some time in April, 1921.

A. F. Victor, *Secretary S. M. P. E.*

Report of the Advertising Committee

OUR committee takes pleasure in calling your attention to the advertising appearing in the Montreal Transactions of our society. The class of advertising and the amount speaks well of the co-operation of our individual members and your committee takes this opportunity of expressing their appreciation of the prompt response from the manufacturers who are represented in this advertising.

The advertising for the year 1920 will increase the income of the society by the amount of $855.00, and we sincerely hope that the compensation to the advertisers will be in like proportion.

Your committee has made no attempt to obtain further advertising for the Dayton Transactions for the reason that they thought it best to see how their first venture in advertising was taken.

Your committee would recommend two general subjects for your consideration, and for the consideration of the new Advertising Committee.

The first recommendation is that a concerted effort be made by individuals in the society to obtain advertising from the producers, and to obtain more diversified advertising from the manufacturers represented in the society and those not represented.

The second recommendation is that our rate classification be revised. This revision to include, first, increased return for preferred space such as space next to reading matter, and the last page of advertising; the second being a differential in price between those companies represented by membership and those companies not represented by membership.

Our present price for advertising space is a quarter page in two issues $25.00, one-half page $35.00 for two issues, and a full page $50.00 for two issues. The committee would recommend that the last page of advertising be sold as a full page for two issues at a price of $85.00 and that the page next to reading matter be sold as a full page at a price of $85.00 for two issues, the inside pages to remain the same price. Your committee would further recommend that an increase in the advertising rate of 10% be assessed against those companies wishing to advertise but which have no representative in our membership. Your committee would further recommend that those companies who have representation in the society be given first choice of preferred space.

For the purpose of action your committee presents the following resolutions:

Whereas there are certain advantages in obtaining certain space in our Transactions for advertising, and

Whereas the society believes its membership should have an advantage over non-members in advertising rates, and

Whereas there are certain points as regards collection which have not been covered heretofore, be it resolved:

First, that our advertising rates to companies having representatives as members of the society be as follows:

Quarter page for two issues $25.00. Half page for two issues $35.00. Full page for two issues $50.00. The last page of advertising, full page, two issues $85.00. Page next to reading matter, full page two issues, $85.00.

Second, that those companies not represented by membership in this society wishing to advertise in the Transactions of the society may do so at a rate 10% above prices quoted, it being understood that companies having a representative member shall have first choice of preferred space.

Third, that the chairman of the Advertising Committee shall at the time the forms for advertising close for each issue, advise the Treasurer of the society of those advertising, the amount of space taken, and the total amount due for the two issues; and further, that the Treasurer shall send out a notice covering half the amount due for advertising at the time each of the two issues is mailed, and further that with these invoices should be attached one copy of the Transactions to go to the advertisers.

Your committee offers the following resolution for your consideration:

Whereas a sustaining member of the society is privileged to one page of advertising for the two issues of the year of sustaining membership, and

Whereas there is a special rate for preferred space,

Be it resolved, that space available for the sustaining members shall be interior pages, and further that should sustaining members desire preferred space, such space may be obtained by a payment of $35.00 in addition to sustaining membership fee of $100.00.

R. P. Burrows, *Chairman.*

REPORT OF COMMITTEE ON PROGRESS

DURING the period since the last meeting of this Society, there has been progress along several lines of the motion picture industry. The condition of any line of activity is reflected, to a great extent, in the improvement in materials, methods and equipment entering into the product. If a comprehensive report of these improvements is made, it is a measure of the growth and development of the industry as a whole. The report presented is, we fear, more or less incomplete, and in this respect it fails as a true indicator of the scope of the work coming within the field of interest of the Society of Motion Picture Engineers.

Projectors:

Among the improvements in standard projectors may be mentioned the use of a pilot lamp or trimming lamp in the lamp house, controlled by a door-switch. When the door of the lamp house is closed, the pilot lamp is out, but as soon as the door is opened for replacing or adjusting carbons the lamp is lighted.

The window in the lamp house door for observing the arc, has been changed into a pin hole camera so that an image of the arc is shown on a piece of ground glass. The new device fits into the holder for the old style glass.

The operation of two machines in a projection room is being made much more convenient than heretofore by the addition of double control handles. These double handles permit the projectionist to control easily the machine at his right.

The spot is also shielded by a double shield which protects the eyes of the projectionist on either side of the machine.

An improved fire guard has been developed for the film gate, which limits the burning of film to a single frame when left in the beam of light.

One manufacturer has made an improvement in the intermittent movement by the use of sleeves or rollers on the pins engaging with the cam thus providing rolling friction in place of sliding friction. The rollers are held in place by a plate on the back of the cam.

A portable projector with a solid bakelite case in place of the usual leather-covered metal case, has been placed on the market. This provides a light weight, fire-resisting construction of good appearance.

Right Angle, Automatic Projection Arc.

With the idea in mind of increasing the general illuminating efficiency of the projection arc, a right angle, high intensity arc lamp has been perfected. This lamp employs a positive carbon rotated by a motor and a magnetic circuit which automatically feeds the

negative. The positive carbon lies horizontally along the optical axis and the negative electrode is so placed as to direct the light rays straight along this axis to the condensing lens.

An Automatic Arc Control.

A single motored projection arc control has made its appearance on the market. This control is marked by its absolute simplicity. It consists of a magnet connected across the arc terminals through a suitable resistance. The armature of the magnet coils is normally held away by an adjustable spring, the latter being adjusted after the proper arc setting has been determined upon. When the voltage across the coil increases the armature is attracted toward the magnet coil, and in so doing, completes the feed motor circuit. The motor, working through a gear ratio of about 800 to 1, feeds the carbons together until they reach a position where the voltage is insufficient to hold the armature against the spring tension. The latter, therefore, causes the armature to break the motor circuit.

Camera Motor.

A manufacturer of motion picture cameras has successfully designed a small compact motor for operating cinema cameras. To be successful, such a motor must be exceedingly accurate in balance so that there will be no vibration present. With this motor in use and operated from a storage battery, the cinematographer is able to give his entire time to the task of keeping his scene in its proper place in the frame.

Color Studies.

Although not technical in its methods of application, it is interesting to note that some of the larger producers of film have been brought to recognize the value of properly preparing the tones of scenes and sets in order that the correct color values and relations may be evidenced on the final black and white screen picture. Color experts are now brought into consultation when lavish sets are being prepared.

Fireproof Structures for Exchanges.

Through the efforts of the various Fire Protective Associations and the film manufacturer, special structures to house film exchanges have been erected or are being erected in the distributing centers of the industry. Many of the older Exchanges represented fire hazards of the worst type. The new buildings are fire-proof in every particular, and have been built to incorporate the ideas of those most experienced in the handling and storage of film.

A. R. Dennington, *Chairman.*

PAPERS COMMITTEE REPORT

MR. KETTERING expressed the chief aim of your Papers Committee, when he said last night that engineering will advance most rapidly by the exchange of information. There are, in general, two ways in which data is exchanged—one, through personal contact and good fellowship; the other, through the presentation and discussion of papers.

It is the privilege of your Papers Committee to have most to do with the latter. In carrying on our work, we have tried not only to secure papers that would interest you and record progress in the various branches of the motion picture industry, but also to accomplish a little broader work by devising ways and means for the committee to become more permanently useful to the Society.

Your committee had thirty-six (36) prospective papers lined up in preparation for this convention. Out of these we finally secured the papers which you have heard. We would call to your attention the fact that the arrangement of an interesting and valuable program is seriously handicapped by those who promise papers and then fail to finish them in time for the convention, or fail to deliver them after they have been finished.

We realize that occasionally conditions arise which necessitate the withdrawal of a paper, or a change of its scheduled time for presentation, but we urge upon authors that every effort be made to prevent such occurrences.

We have made earnest efforts to find out from the membership of the Society the subjects in which they are most interested. We have even written a letter to every member of the Society asking for suggestions on convention papers. This has met with very little response. In lieu of such information, we have analyzed the papers that have been presented and tried to secure subjects on which information is more or less lacking and which are of importance in the industry.

However, the convention is primarily yours, and if you will tell us what you want in the way of papers, we shall make every effort to try and secure them for you.

We would suggest, that before this convention is over, while things are fresh in your mind and you are enthusiastic, you get in touch with some member of the Papers Committee and make suggestions for the Spring convention, as your committee starts work on the Spring convention the day that the present convention closes.

After a convention is over, your Papers Committee has experienced considerable difficulty in securing for use in the Transactions complete texts, photographs and drawings for the papers which have been given. Unless the Transactions are issued promptly after a convention, they lose materially in value.

There is a great deal of work entailed in the preparation of the Transactions; not only do the texts, drawings, etc., have to be

secured edited and turned over to the printer, but the proof has to be read, sent to the author for correction, and perhaps reprinted and returned for further correction. All of this takes time and the burden of the work falls largely on the Committee on Publications.

It is absolutely impossible to publish the Transactions promptly unless the authors cooperate and send in their material shortly after the convention.

Next year, by action of the Society, you have authorized the carrying out of the recommendations which your Papers Committee has made; namely, that papers be printed and distributed in advance of the convention and that at the convention, extracts or synopses only, of the papers be read; the majority of the time being devoted to discussion.

You have also authorized having a public stenographer present to take down the discussions, and that the discussions appear together with the full text of the paper in the Transactions. Your Committee believes that as the paper itself is only one man's opinion on the subject, it will be made much more valuable when thoroughly discussed by numerous people. In order to accomplish this, however, it is *absolutely necessary* that the *texts* of papers for the convention *be in the hands of the Papers Committee four weeks in advance* of the convention. We would call this to the special attention of prospective authors for the Spring convention, asking their cooperation in this matter.

You have also, by recent action, agreed to your Papers Committee recommendation that extracts of the discussions given at the present convention accompany the papers when they appear in the Transactions. You will realize that it is impossible for our secretary to record long-hand the various discussions and we, therefore, point out to those who discussed papers the necessity of promptly sending either to the secretary or to the Papers Committee their discussions.

We would also recommend that extracts of actions taken by the Board of Governors, and by the convention as a whole, appear in the Transactions.

By way of more permanent work, your committee recommended some time ago that a new committee be formed, to be known as a "Committee on Progress"; this committee to report at each convention things of interest which have been accomplished in the various branches of the industry since the last convention. We are proud of the two reports which we have had from this committee and think they have demonstrated the value and permanence of this work.

We believe that it would be of great assistance to extract any articles appearing in the Transactions of other technical societies, or in the press, which pertain to the work of the Society of Motion Picture Engineers, and we believe that a permanent committee should be formed to give such a report at each convention, this being a part of the committee's work, the chief aim being cooperation with other organizations. We would, therefore, recommend the formation of a Committee on Reciprocal Relations.

We believe that the Utilities Committee, which was appointed at the request of the Papers Committee, proved its usefulness and service at this convention, and we trust the committee will be retained as a permanent part of our Society.

Your committee has enjoyed its work during the past year and wishes to thank the Society as a whole for their support, and in particular the members with whom we have worked more directly. During the course of this work we have perhaps learned some things and secured some data which might be of assistance to the Papers Committee for the coming year, and we should be very glad to place such information in the hands of this committee whoever they may be, and cooperate with them to the best of our ability.

L. C. Porter, *Chairman.*

Report on Committee to Consider Correspondence Course for Projectionists

IN order to get some idea of what should be included in a correspondence course for projectionists, a general outline covering the principal subjects has been prepared. This outline is not expected to be complete in its present form, but may be considered only as a skeleton to be developed as the work progressed. The outline follows the general plan adopted by the International Correspondence Schools, and an effort has been made to present the various subjects in a logical order, though it is realized that there are a number of discrepancies in the first outline which has been made up. There are also a number of omissions in listing apparatus, as it has not been practicable to spend the time which would have been required to make a complete and detail outline of the complete course.

Plan for Obtaining Material:

Little difficulty would be found in obtaining from various manufacturers of equipment special information regarding the apparatus or devices which they manufacture. This is the plan which has been followed successfully by the International Correspondence Schools. In some cases an employee in a manufacturing establishment has been hired by the Correspondence Schools to write a booklet or a series of booklets giving details of the apparatus manufactured. I doubt if it would be necessary to hire any employee in the various industries connected with the motion picture business, as the advertising value which these manufacturers would obtain would amply repay them for any effort in furnishing information.

Preparation of Material:

After obtaining descriptions of apparatus and the important facts involved in any special section, it is absolutely essential that this material be carefully edited. The entire success or failure of a course depends largely upon the editorial work. It must be kept continually in mind that the material is to be presented in such a way that it will not only be interesting but will be easily understood by the reader who has not had the advantage of any technical training, and perhaps nothing more than a common school education. The text should be illustrated with very complete diagrams and half-tone cuts. Many of the points would require the making up of wash drawings in order to bring out the details which would need to be emphasized. Therefore, in addition to the editor, it is important that the illustrations be made up by someone who has had experience with or is conversant with the making of illustrations for correspondence courses.

Printing and Distribution:

After the material has been prepared for printing, it is essential that a high quality of paper and good clear type be used, as, otherwise, the effort to present the subject matter in a clear, concise manner may be almost offset by a poorly printed page. Economy in the matter of paper in press work would be ill-founded in the making up of a successful correspondence course.

In the outline which has been made there are ten general subjects covered. It is estimated that these ten subjects would require booklets of 25 to 100 pages each, and the average would probably be 50 or 60 pages.

Estimated Costs:

Assuming that provision be made for distribution of 5,000 copies of the correspondence course, and that the total number of pamphlets in the course is ten, and that these pamphlets would be issued at different periods, the printing cost would probably be about $1,000 per pamphlet or a total of $10,000. The editorial work required would mean at least one year, and the estimated cost of this work is $3,000. Time of drafting required for illustrations would amount to approximately $2,000. Incidental expenses—traveling, etc., $1,000. The estimated cost of preparing the course would, therefore, be $16,000.

There are additional items of advertising, and the cost of distributing the books to subscribers, which are not included, but it is very doubtful if any study course could be prepared for less than the amount given.

A. R. Dennington, *Chairman.*

Extracts of Action taken at Board of Governors Meeting, Hotel Miami, Dayton, Ohio, October 10, 1920

THE following applications for active membership were presented and accepted.

Mr. F. Morrison, of Barr & Stroud, Ltd., England.
Mr. P. R. Bassett, Sperry Gyroscope Co., Brooklyn.
Mr. C. A. Ziebarth, Bell & Howell Co., Chicago.
Mr. A. S. Howell, Bell & Howell Co., Chicago.
Mr. J. H. McNabb, Bell & Howell Co., Chicago.
Mr. Proksa, Universal Tool & Die Co., Chicago.
Mr. H. F. Barnes, Edison Lamp Works, Harrison, N. J.

The following applications for associate membership were presented and accepted:

J. Hornstein, Howell Sign Equipment Co., New York City.
H. A. R. Dutton, Exhibitors Supply Co., New York City.
I. L. Nixon, Bausch & Lomb Optical Co., Rochester.
H. L. Gage, Toronto, Canada.

The following resignations were presented and accepted by the board:

D. J. Bell, C. B. DePue.

The Treasurer stated that the Society's finances were in a healthy state, having $2459.24 cash in the bank, about $100 due on 7½ membership dues still unpaid, about $470 due on advertising and considerable coming in as dues from new members. Against this, all outstanding bills amount to about $900.

The Treasurer was instructed to present a detailed statement showing the Society's net assets at the closing of this year's books.

The Treasurer stated that he had had himself bonded as treasurer of the Society.

It was pointed out that through a typographical error the name of Mr. B. R. Proctor was omitted from the latest membership list. This will be rectified at once. The secretary is to make a complete list of all members in good standing a part of the minutes of each meeting.

The question of the sale of Transactions was discussed. The Secretary suggested the preparation of a pamphlet giving titles and synopses of all papers presented before the Society to be distributed to projectionists and others.

Mr. Burrows suggested supplying salesmen of motion picture equipment with copies of the Transactions to be purchased by the salesmen or the concerns they represent.

Mr. Campe suggested running half page advertisements in the trade journals.

It was finally decided to prepare the booklet suggested by the Secretary and to run a small advertisement bearing the Society's emblem in the trade papers stating that such a pamphlet and price list would be sent upon request and receipt of postage. It is anticipated that this will result in the sale of many Transactions.

It was decided to charge $.25 for any of the Transactions previous to those of the Pittsburgh meeting; $1 for the Pittsburgh Transactions and all later ones until further action is taken.

Mr. Roebuck exhibited the new application blanks and stated that two had been sent to each member of the Society.

It was decided that at the next convention the papers will be printed and distributed in advance and that at the meeting, synopses only will be read, devoting the majority of the time to discussion. Each speaker is to be limited to a definite time. A court stenographer is to be provided to record the discussions. These will be edited by the Papers Committee and appear with the complete text of the paper in the Transactions.

The secretary was instructed to send one set of the Transactions of each meeting to any and all other societies throughout the world whose work is similar to or bears on that of our own and to secure their transactions in exchange; these transactions to be extracted by a committee and presented as part of the Papers Programme at each meeting hereafter.

It was decided to use the Society's official seal on all future membership cards.

L. C. Porter, *Secretary pro tem.*

History of the Motion Picture

By C. Francis Jenkins

I HAVE been asked by your Papers Committee to prepare a sketch of the conception, early history and development of the motion picture, but to compile an accurate account sufficiently complete without being too lengthy is not an easy task.

Where the motion picture idea originated I have not found out, though a hundred years before the Christian era, Lucretus strangely wrote his friend thus:[2]

"Do not thou moreover wonder that the images appear to move and appear in one order and time their arms and legs to use; for one image disappears and instead appears another arranged in another way, and thus seems each gesture to change; for you must understand that this takes place in the quickest time."

This is an exact description of the motion picture of today, and if this is really what he meant, then it took two thousand years to get a suitable picture ribbon and a proper machine to handle it. And it will be noticed that the subject naturally divides itself into these two main elements, i. e., the picture-carrying vehicle and the handling mechanism therefor. The mechanism is of two kinds, i. e., one of them continuous movement, the other intermittent movement of the picture carrier at the illuminated aperture. The process, as we know it today, is likewise divided into two steps; the first a photographic analysis of the animated subject, the second a synthesis of the elements into which the subject was divided by the analytical process.

The success of the attempt to simulate animation depends initially upon persistence of vision, that faculty of the human eye which enables the retina to hold onto a light sensation for an appreciable time after the light is cut off. And curiously enough this phenomena seems to have been first mentioned by a blind man.

The motion picture is not a sort of Minerva-birth of inventive genius, but like all notable achievements in mechanisms has had a long line of predecessors, for the difficult problem of recording and reproducing motion did not yield without much preliminary fumbling.

Obviously it would lengthen this paper beyond acceptable limits if description were made of the work of all who have contributed to the result in the form finally adopted and practiced at this time. I shall therefore endeavor to confine myself as far as this may be done to mention of the contributions of those who in turn first added a new step in the development of the idea.

By a process of knowledge additions and eliminations the motion picture of today reduces itself roughly to six historical periods; the first (1) a series of related picture elements; (2) the adoption of

[2] De Rerum Nature, book IV, verse 766.

photography to secure them; (3) the use of a single camera; (4) of perforated film; (5) of intermittent film movement; and (6) in making the period of illumination exceed the period of change or substitution of a new picture element, or frame, for the last in sequence throughout the series.

The first motion picture mechanism we have any record of is the zoetrope, or wheel of life, though its origin is buried in antiquity. It may be that this is the device Lucretus was writing about. It usually consists, as you all doubtless well know, of a paper cylinder having equi-spaced axial slits cut through its wall. Between the slits on the inside were arranged sketches of successive phases of an object in motion. By whirling the cylinder and viewing the sketches through the slits as they passed the eye one got the sensation of an object in motion.

The Zoetrope

The picture series were also put upon a slotted disc (this form may have antidated the drum type) and were viewed by looking through the slots at the reflection of the pictures in a mirror as the disc was whirled.

The first attempt at projection followed this line, that is, transparencies were mounted in disc form and illuminated from the back, a projection lens imaging these on a screen as the successive pictures of the series were momentarily exposed in the field of the lens.

Plateau, who seems first to have made up such a mechanism, mounted sixteen pictures on his disc, suitably illuminated them through a whirling opaque shutter having a single radial slot therein, the shutter disc rotating sixteen times as fast as the picture disc. Though blind, Plateau appears to have given diligent study to this persistence of vision phenomena, and at this early date, 1849, curiously enough, hit upon the same picture frequency now universally used. This picture disc, intermittently illuminated, was subsequently employed by several experimenters.

Another form was exactly the reverse of this plan, for instead of a single stationary lens and stationary light with a 16-picture transparent disc revolving between, consisted of a stationary disc with 16 pictures and 16 lenses, a single lens mounted in front of each picture, while the light whirled around to momentarily pass through each picture and adjacent lens. As all the lenses were adjusted to register at a single spot on the screen, the composite on the screen appeared, by persistence of vision, as a single uninterrupted picture.

The idea of simulating motion by intermittent illumination of a series of related picture elements seems to have been the preferred method for more than a hundred years, the last of the line being Edison's Kinetoscope of 1894 (to be described later).

The picture series were first made in a camera in 1860, to the best of my knowledge, by Colman Sellers, an engineer, who, in one form, pasted the photo prints on an endless band for exhibition.[3]

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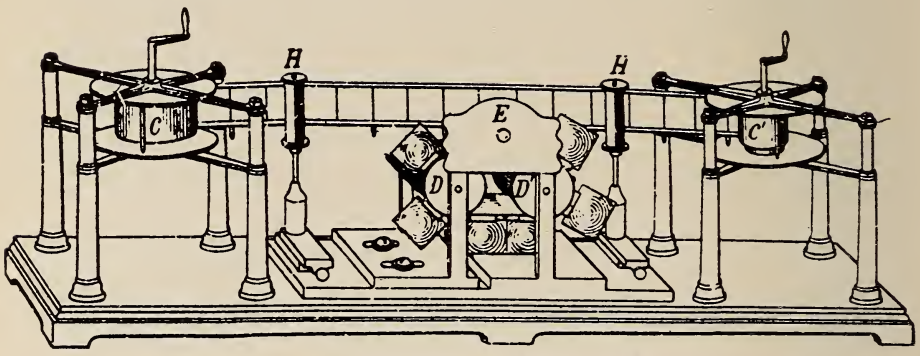
[3] Sellers, U. S. Patent No. 31,357, issued Feb. 5, 1861.

In 1894, I met Mr. Sellers who described his devices to me and gave me photographs of them and also strips of pictures used therein.

An acquaintance of Colman Sellers, and likewise a Philadelphian, Henry R. Heyl, also made camera plates (of a dancing couple in action) making from the negatives wet-plate lantern slides which he mounted disc-wise, and revolved, step-by-step, in the light of a projection lantern. He gave a public demonstration at the Academy of Music, Philadelphia, Feb. 5, 1870.[4] I have paper prints off the negatives, which he gave me in 1895.

An examiner in the U. S. Patent Office, some ten years after allowing me a patent on a perforated picture strip in continuous and synchronous motion with a plurality of lenses passing a fixed open-



Projector with plurality of lenses.

ing in a camera, called my attention to an anticipating French publication, of March 1, 1864, in which Sr. Ducos illustrated and described much the same thing, i. e., a flexible picture band carried along by a sprocketed drum, synchronously with a plurality of lenses.[5]

The first use of the now almost universally employed geneva gear or star-and-cam in projectors appears to have been made by A. B. Brown, in 1869.[6] However, the use of this type of intermittent gear is practically the only interest his contribution has for the historian.

Marey, a French scientist, employed the zoetrope, the slotted cylinder described earlier herein, with solid figures instead of pictures, modeled in imitation of successive phases of an animal in action, which not only gave the action but the placticity of solid bodies. One of his instruments of this type is still to be seen in the Museum of the Paris Physiological Station.

A variation of the picture-carrying drum, employed as a projector, had a series of vertical mirror-strips for reflecting the light beam which carried the picture to the screen. It depended for success

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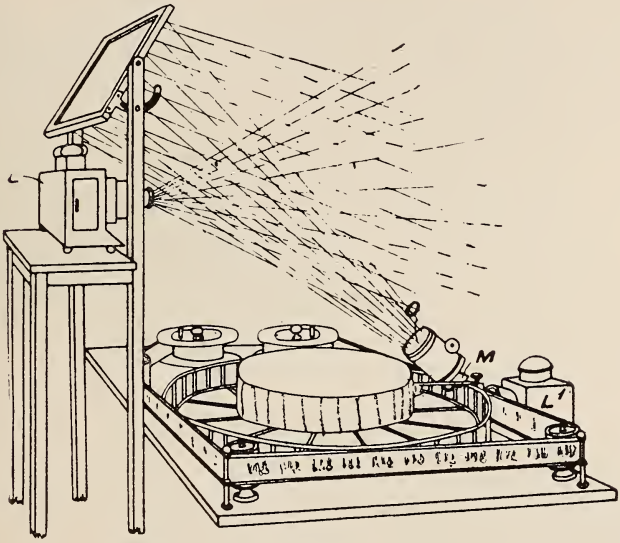
[4] Franklin Institute Transaction of this year (1870).

[5] Unpublished French Patent, July 5, 1864.

[6] U. S. Patent 93,594, 1869.

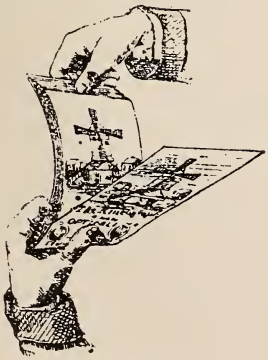
upon the reflection phenomena that, to accomplish the desired result, the angular movement of the mirror must be but one-half that of the picture movement. Reynaud, in 1889, made such a device



Reynaud's improved version of the Zoetrope.

which was to be seen on the boulevards of Paris until the present type projector deprived it of public favor.[7]

Aside from the ribbon form of picture carrier, another which attained considerable popularity in its final and perfected form consisted in mounting the picture series as the leaves of a pad or book, which, bent back and exhibited by slipping from under one's thumb, brings the picture into sight in such rapid succession that a very good motion picture is produced.

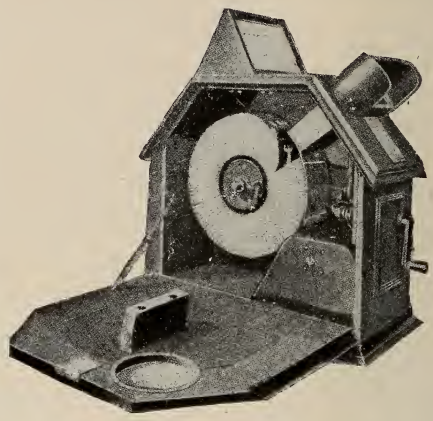


The Thumb-book

The first mention I have been able to find of these thumb books, as they came to be called, was the invention of Linnett in 1868.[8] They appeared from time to time in one form or another, sometimes being mounted in a holder with a mechanical detent to press back the cards.

[7] British Patent 2,295 of 1889.
[8] British Patent No. 925 of 1868.

The most pretentious of these instruments was the Mutoscope of Herman Castler[9] in 1895. The picture cards stood out radically from a drum to which they were attached by their bottom ends, a thousand or more on a single drum, and these slipping from under a detent exhibited the pictures thereon with smoothness and precision. It was a coin operated machine and "picture parlors" equipped with Mutoscopes were established in the large cities, seaside and mountain resorts and pleasure parks, holding the public favor until the advent of the 5c-movie theatre.



The Mutoscope

The Phantascope

The Messrs. Lumiere, of France, brought out a similar machine which they named the Kinora. The striking feature of this machine was the curved picture-carrying cards, curved to add resiliency.

My own contribution to this line was a Phantascope toy,[10] in which a flexible band was employed, the cards being attached thereto by their lower ends and having a spaced relation of about five thousandths inch. This close spacing of the cards assured a firm adhesion to the band and to each other when a flexible glue was used.

But it is to the persistence of Edward Muybridge that we are indebted for the most scientific research in motion analysis, work which he began in 1879. His animal studies became classics with artists. Wet plates only were then available and he used above half a million of them in a plurality of cameras arranged in order along a track over which his subject was required to pass. He thus obtained consecutive impressions at regular intervals of time and distance during a complete stride.[11] His first work was financed by the

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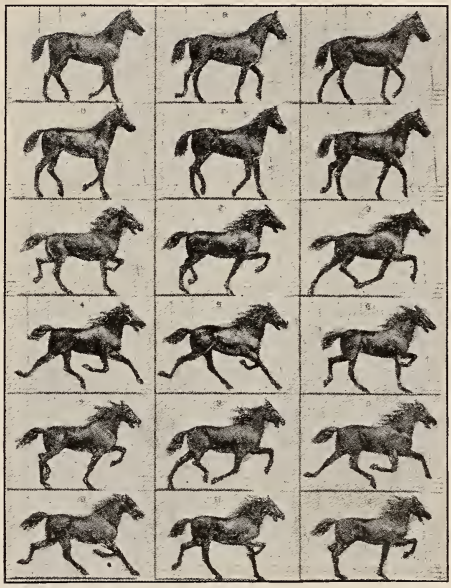
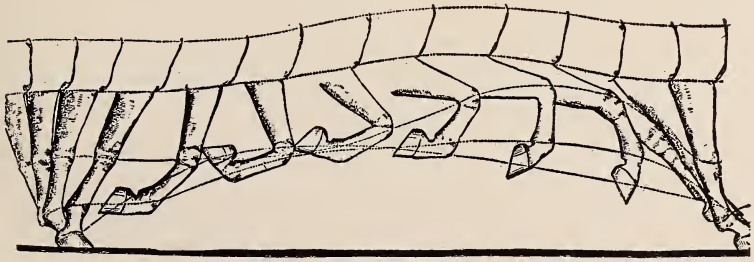
[9] U. S. Patent No. 549,309, 1895.
[10] U. S. Patent No. 779,364, 1905.
[11] Franklin Institute Journal, April 1883.

Hon. Leland Stanford, of California, a lover of fine horses.[12] Between 1883 and 1887, he was engaged in like work at the University of Pennsylvania, where his "Animal Locomotion" was published.



Some results of Muybridge's experiments.

On February 27, 1888, Mr. Muybridge interviewed T. A. Edison as to the possibility of combining his Zoaproxiscope projector with Edison's phonograph, but without result, though Mr. Edison did exploit such a combination some years later.



Dr. Marey's experiment with phases of animal locomotion.

The next to come prominently into notice was Dr. Marey. Sometime after meeting Muybridge in Paris, in 1881, where Prof. Muybridge was exhibiting at the Electrical Exposition, Marey set

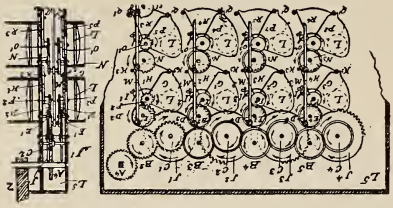
[12] The Century, July 1, 1887.

about to determine by graphic methods the trajectories, velocities and accelerations of moving parts of the human body, acquiatic locomotion, etc. At first, he used plates but later, 1888, used "a long roll of sensitive film" intermittently fed past the exposure aperture.[13] His work has a permanent value to science.

In 1887, Auchutz published[14] a description of his tachyscope, a device which was later shown at the World's Fair, Chicago, 1893. The apparatus consisted of a glass wheel the pictures on which were lighted by the flash of a vacuum tube as they came into position; though the machine is the same as that described by Donisthrope, of London, in *Nature*. issue of January 24, 1878.

To concentrate a considerable length of entertainment on a convenient area a disc picture carrier was attempted by several inventors. In one scheme a glass plate was employed upon which series of pictures were spirally arranged, as in the Anthony device.

A British patent of 1900 to Rosenberg discloses another plan, a film having two rows of pictures thereon, each row being half of the whole show. At the end of the first row the film was shifted and run in the opposite direction to show pictures of the second row. Edison in his home projector of 1911 followed the same scheme.



The LePrince Patent

In 1886 Augustus Le Prince, of New York State, filed an application[15] for U. S. Patent which disclosed transparent picture ribbons having a row of perforations along each edge of each film. Four such strips were used in the machine, four pictures being made on each in succession behind sixteen lenses. A single lens modification is suggested, with perforated film driven by a sprocketed drum.

It is curious that those who came nearest anticipating future accepted methods and mechanisms should have failed to follow up their work. As another shining example I might cite Mr. Levison, who publicly exhibited at the Brooklyn Photo Club an apparatus

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[13] Academy des Sciences, Comtes Rendus 1888, CVII, page 677-678.

[14] Philadelphia Photographer 1887, p. 328-688.

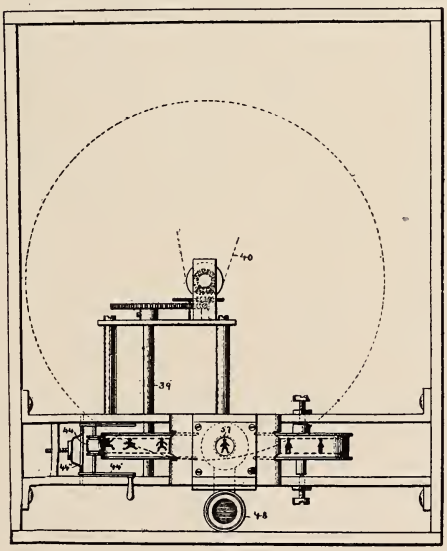
[15] Serial No. 217,809; Patent No. 376,247.

much like present day devices; it had flexible film, moved step by step, and behind a single lens.[16]

Plates, cards, paper strips, drums and glass discs had been used for animated pictures, but when in 1885 Rev. Goodwin invented the transparent celluloid flexible film the way was opened to rapid advance, for the necessary unlimited capacity in the picture carrier was then possible.

In 1889, Mr. Dickson began, at Thos. A. Edison's direction, the development of a picture machine.[17] News of what was being done appeared in print from time to time and the summer of 1894 saw the beginning of the public exhibition of his Kinetoscope, a box into which one looked to see picture in animation.

The picture ribbon was passed continuously between a small lamp and the eye of the observer, the view being cut off by a rotating disc about a foot in diameter and having a one-eighth by one inch radial slit therein near the periphery. Through this flying slit the observer got a momentary sight of each picture frame as it



Appearance of first Kinetoscope.

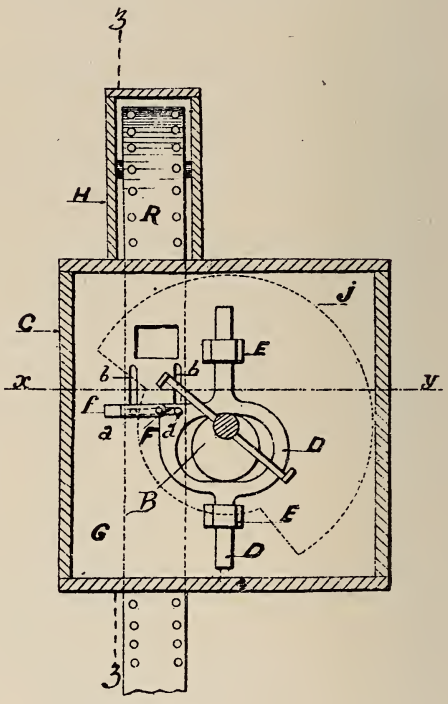
came into position above the light. The frames passed at the rate of 46 per second, a high speed being required because of the instantaneous view and meagre illumination. The pictures were small,

[16] Brooklyn Eagle, and Brooklyn Citizen, both of June 14, 1888.

[17] Scientific American, June 20, 1891, also U. S. Patent 493,426.

of course, but excellently done. The excellence of the Edison pictures without doubt proved a stimulus to the rapid development of the art, far more than any contribution in mechanical design or new methods, as was later demonstrated when the courts held that the Edison patents and re-issues were anticipated and invalid.

Among the early English workers were Friese-Greene and Mr. Evans who exhibited a camera before the Bath Photo Society, February 25, 1890, and in 1895 were working on a projector, work which was concurrent with the work of the Lumiere Brothers in France. The Lumiere camera was also used as a projector, however, and as such came to America in 1897.

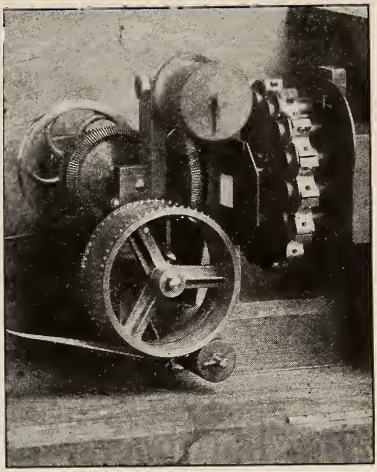


Lumiere Camera

The American Biograph, built by Herman Castler in 1896 was one of the very best of the projectors of these early development years. He worked on the theory that the larger the frame the sharper the definition on the screen because of the less enlargement required. This machine used 2¾″ width of film. The film, unperforated, was advanced through the projector by the griping action of mutilated cylinders which contacted for only a fourth of a revolution. The resultant screen picture was excellent, but like all the other mechanisms employing film differing from the generally accepted standard, had its day, played its part and dropped from sight.

In 1890, I began work on mechanisms for recording and reproducing motion. Two systems were developed side by side; one employed intermittent motion at the picture aperture, the other continuous motion. Cameras were first made, in which film was used, split to width in the dark from Kodak film bought in local photographic shops. These pieces were spliced into strips, sometimes twenty-one feet long, if I was lucky. Prints were made from negatives exposed in the cameras—usually in the continuous motion camera, for it made the steadiest pictures, though projection was mostly in the intermittent machine which had no interrupting shutter and therefore gave most illumination.

The continuous motion mechanism consisted of a rotating disc carrying a plurality of matched lenses arranged around its periphery and passing in single line sequence across an adjustable opening in exact synchronism with a film moving downward in the focus of the lenses. Different mechanisms were made, with an equipment of lenses ranging from five to forty eight and in spaced relation depending on the height of the frame chosen.



Continuous motion mechanism with plurality of lenses.

In the intermittent mechanism the film was illuminated for about seven-eighths, and moved in about one-eighth of a period. A "beater type" was first employed and later followed by the geneva gear, a gear found in many makes of watches to prevent winding the spring too tight.

My work was my own, but viewing the art in historical retrospection from this late day, it is evident that the solution of the illumination problem was my only original contribution to the art as practiced from 1890 to the present time. I must confess that I don't quite understand why the thing wasn't hit upon by someone previously, it was so simple and so perfectly obvious when once done; like the half turn of the screw which made the constant contact transmitter, which, in its turn, made the telephone a commercial article.

All my old apparatus was acquired by the United States National Museum in 1895 and there it can still be seen (on exhibit in the Graphic Arts department).

My projectors were motor driven and by some accident of design were built left-handed, a type which has since been followed, consciously on unconsciously, in the design of machines the world over.

Exhibitions to friends were given from time to time in 1891, 1892 and 1893, though my first exhibition of which any account appeared in printed publications, was in June of 1894.[18]

In March following I secured the financial assistance of a local man and we built three copies of this early machine and exhibited them at the Cotton States Exposition, Atlanta, 1895.[19] These were the first of picture shows in a building built exclusively for the purpose.

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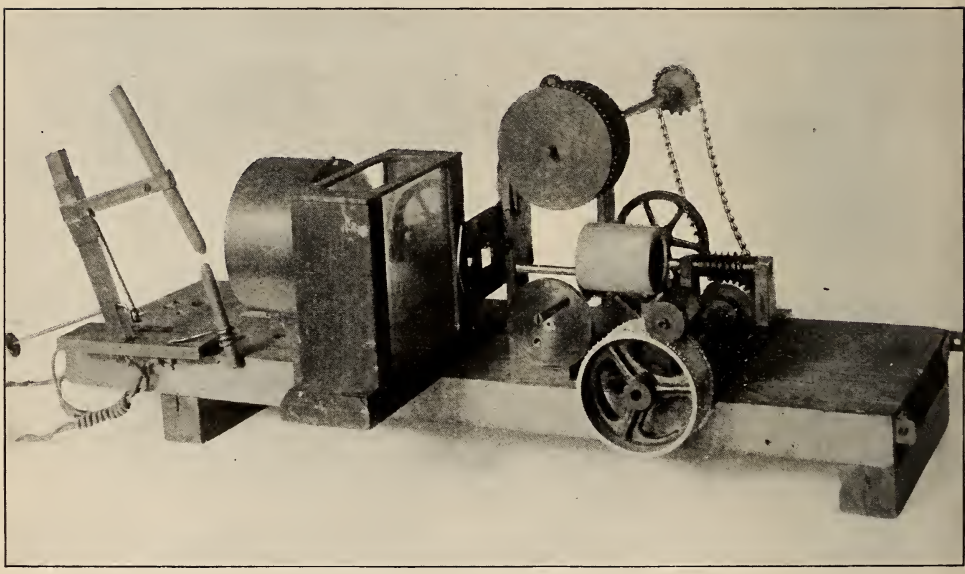
[18] Richmond Telegram, Richmond, Indiana, June 6, 1894.

[19] Baltimore Sun, Oct. 3, 1895; Atlanta Journal, Oct. 21, 1895; Albany, New York, Times-Union, Oct. 21, 1895.

In the winter following, I demonstrated the original instrument, the Phantoscope, before the Franklin Institute of Philadelphia[20] and at the close of the demonstration it was voted that the matter should go before the proper committee to determine whether it ought to receive scientific acknowledgment. The Committee in due course recommended the Elliott Cresson Gold Medal and published its findings in the Journal for three months. Thereupon the proposed award was vigorously opposed by two interested gentlemen, but after many months of taking testimony and considering evidence and data submitted, the originally recommended award was made. Eighteen years



The original Jenkins lateral projector.

later a second award was made, the John Scott medal, for improvements, i. e., lateral projection, as demonstrated in a machine which I later christened the Graphoscope.

Efforts have been made from time to time to exploit synchronized pictures and sound, but without success. There is no difficulty in synchronizing. This has been accomplished in several ways by those engaged thereon, my own scheme being to put the sound record on the film as a sinuous edge so that accidental destruction of a part of the film would take out as much sound as picture, and when spliced again would still be in synchronism and without any adjustment of mechanism. The public, however, did not favorably receive any of the singing pictures and all such schemes disappeared when the novelty of a single exhibition had passed. The silent drama

[20] Franklin Institute Bulletin December 1895 and Franklin Institute Journal, January, 1896.

is attractive to a very large extent, I think, because it *is* the silent drama.

Stereoscopic motion pictures have been the subject of considerable thought and have been attained in several ways, as described in the October, 1919, transactions of this Society, but never yet have they been accomplished in a practical way. By practical, I mean, for example, without some device to wear over the eyes of the observer. It is generally conceded that its acceptable accomplishment would enhance the beauty of the motion picture.

Motion pictures in natural color have been attained by several persons, one of the first to have wide public exploitation was that employed by Smith and Urban (Chas. Urban, one of our members). The film had color stencil frames alternating longitudinally of the film and which were projected respectively through red-yellow and green-blue tinters so that the film running through the machine at twice standard speed produced a composite screen picture in natural color and motion.

Gaumont in 1913 had a color scheme in which three rows of frames were arranged side by side on a wide film, each row being projected through its appropriate tint and, superimposed, produced a screen picture in natural color. With a synchronizing attachment sound was also added giving "talking motion pictures in natural color."

As each of these schemes required special apparatus difficulty was experienced in exploiting these processes and they fell by the wayside.

The process which will succeed is that which fits standard machines without change. Such, for example, as that patented[21] by Arturo Hernandez and skillfully developed by one of our members, Mr. Kelley. This was demonstrated at our Philadelphia meeting and described in the transactions of November, 1918, and April, 1919. It consists, as you will remember, of a double coated film, the red-yellow frames being on one side and the blue-green frames on the other side of the film, each side tinted in its proper color throughout the length of the film. Such a natural color film can be run in the standard projector without change, and can, and often is, put into a split reel with monochrome film.

The suppression of flicker (and resultant headache) was the next problem to attract attention and the first mention I find is in 1900[22] and the description says that "the shutter rotates once in the interval between the movements of the film."[23] But as more commonly practiced flicker is subdued by adding one or more blades rather than by rotating the shutter oftener.

In France the Pathe Brothers have a notable establishment in which the requisites for the entire motion picture process are

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[21] U. S. Patent 1,174,144.

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[22] British Patent No. 2283 of February 5, 1900.

[23] From Digest in U. S. Patent Office Library.

produced, i.e., raw stock, cameras, laboratory equipment, studio and projectors. In England Chas. Urban for several years maintained a similar plant and his accumulation of educational and scientific subjects are probably unequalled anywhere.

We have no similar establishment in America, the Yankee being more prone to specialize. And my sketch would be incomplete should I fail to mention the impetus initially given to quality picture production by Messrs. Bell and Howell, makers of fine cameras and printers. Another who has made himself paramount in his specialty, picture printing, is Mr. Rothacker. Both Bell and Rothacker are members of our Society. And just here let me note that quality production has been possible by the uniformly high standard of raw stock furnished by George Eastman, represented in our Society by Mr. Blair.

Projection has not been developed to the same high degree, perhaps because the accomplishment is far more difficult. The analytical end of the motion picture process has always been the least troublesome, principally because of the ample time latitude of film movement in the camera and printer. The projector still lacks the 100% quality for 100% of time of a completely developed machine, in addition to an efficiency of but 50% in light utilization.

And yet I think it one of the most remarkable mechanisms extant. Consider its intermittent sprocket for example; it handles a thousand feet of fragile and delicate film per minute, with a start-and-stop motion, at a speed of 150 feet per second at the maximum point, stopping it with so nearly microscopical exactness that, magnified, say, four hundred diameters, and repeated sixteen times a second, the unsteadiness is almost nil.

As for players our art now has such popularity that few actors and actresses of the speaking stage have been able to resist the lure of the silent drama, despite their prejudice, though none of them has made so great successes as those of less or no foot-light experience. Apparently stagecraft and cameracraft don't "gee." Certain it is that new names have attained stellar brilliance in the pictures, the new medium of expression having developed a new type of artist both in acting and in direction.

But we should not forget that while our art as an industry is the fifth largest in the world, and money has been spent with reckless disregard of values, it was the courageous spirit who established the first 5c movie house who made such expenditures and such returns possible. This was the real beginning of the expansion which made an industry of a scientific plaything, and a film exchange system which has endured to this day. For just as the central exchange made the telephone widely useful, so the movie theatre made the motion picture a profit paying entertainer.

So, as Sargent happily puts it, for fifteen years now we have had a device for dramatic representation which has given us every form of entertainment known to man since the beginning of time. We present the story teller in a pantomine far more effective than mere words alone; we show every form of spectacular reproduction

in a splendor never dreamed of by a Caesar; we present every human emotion known to exist in a realism and costume true to nature; we multiply the magic lantern a thousand-fold in every reel; we bring every distant country, every strange people, every quaint custom, every new and wonderful invention, every scientific discovery; all this we bring to the stay-at-homes and an humble coin pays the fiddler. The child of today has seen more of the world than did the traveler of yesterday.

Many great enterprises have begun with the doing of some very simple thing. So in motion pictures when the opening in the shutter was enlarged scientific grouping stopped and the development of an industry began, an industry grown already to great magnitude. But I firmly believe that because of its universal usefulness, the ability to convey information between all peoples of the earth (for you should remember that it is without language or literacy limitation), the motion picture is destined ultimately to be the greatest single industry known to mankind. I think, therefore, fellow engineers, we may justly be proud of our vocation.

REPORT OF THE OPTICS COMMITTEE

SINCE the last meeting of the Society the Optics Committee has repeated its former tests on the effect of color in projection, using a method not subject to some of the possible errors of the former one. When the film itself was dyed there was a chance of the dyeing material affecting the clear and opaque portions of the film to a different degree. Accordingly in the recent tests two uncolored loops from the same film were used, the picture being of a stationary object to insure equality. Each was then run through a machine—the machines being as nearly alike as possible—and the two pictures thus obtained were thrown side by side on the screen as before. A large piece of dyed gelatin was held just beyond one objective. The observers sat near the center of the room, so as to see both screens from the same angle, and recorded which picture seemed brighter, which clearer, and which of greater contrast—the colored or the black and white.

A metal mesh that intercepted half the light was next put over the objective used with the uncolored picture, and a second record was then made by the observers. A third and fourth record were made with the uncolored light reduced by meshes to ¼ and ⅛ of its initial value respectively. Before each comparison the screen was darkened and the room lights turned on to bring the eyes of the observers to approximately the same sensitivity each time.

Above is given a table of the results. Columns 1 and 2 give the number and name of the color, column 3 the percentage of the light falling upon the filter from a tungsten filament at 2880°K, that is transmitted. This percentage had been previously measured with a flicker photometer.

There are nine columns under each heading, Brightness, Clearness, and Contrast. The figures under columns *b* denote the number of observers that thought the brightness, clearness, or contrast of the colored picture to be equal to the uncolored one without intercepting mesh. Under columns, *d, f,* and *h,* is given the number who considered the colored picture equal to the uncolored picture when the latter was reduced by a mesh to ½, ¼, or ⅛ full brilliancy. Similarly columns *c, e* and *g* give the number of observers who recorded the point of equality as lying between the adjoining columns, and *a* and *i* beyond. For example, in color 1*a* three observers thought the contrast in the colored picture to have been less than in the black and white at full brightness, but greater than in the black and white reduced to one-half brightness.

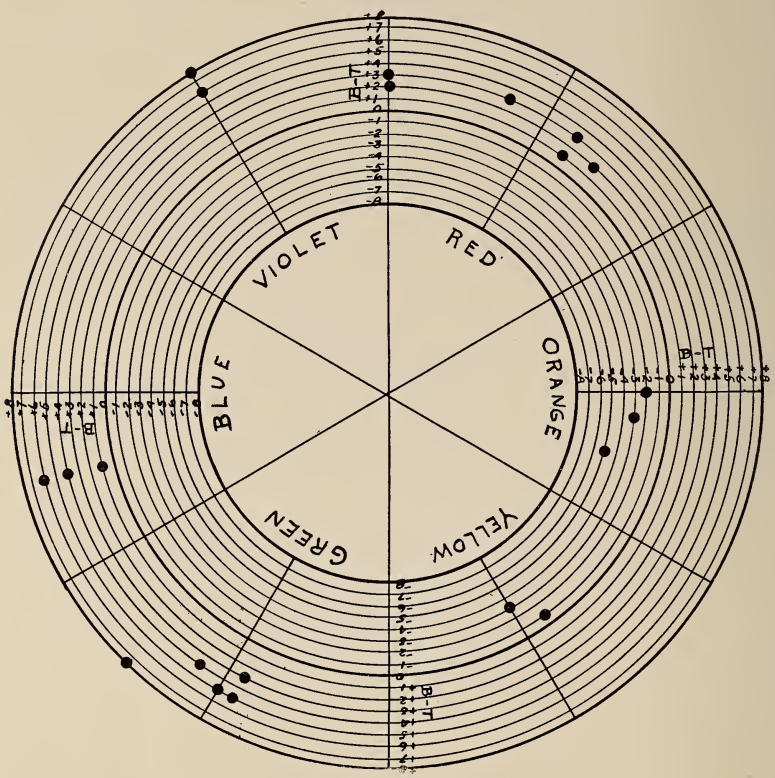
The colors were run through twice. The results of the first trial are given in the top half of each square and of the second in the lower half. In every case the readings indicate a gain by the colored picture in relative clearness and contrast, as well as brightness, each time the brightness of the uncolored light is reduced. This of course means that when any observer has decided that the

TABLE

No.	Transmission	Color	BRIGHTNESS	CLEARNESS	CONTRAST	AVERAGE	Transmission	B-T
			a b c d e f g h i 1 ½ ¼ ⅛	a b c d e f g h i 1 ½ ¼ ⅛	a b c d e f g h i 1 ½ ¼ ⅛	B. Cl. Co.		
1a	35	Purple	4 1 4 1 3 3	1 1 6 1 1 3 2	3 1 4 1 2 2 2	d- e e	e	2
1b	24	Purple	1 1 5 1 2	2 3 1 1 1 1	2 4 1 2 2 1	e e e-	f	3
2a	28	Scarlet	1 5 2 1 3 1	1 4 2 2 2 1	5 2 1 2 2	e e e-	f	2
2b	45	Scarlet	5 3 1 2 3	4 4 1 1 1	4 3 1 1 4 1	d d- e	d-	1
3a	70	Orange	3 4 1 2 3 1	1 4 3 2 3 1	3 3 2 2 3 1	d d- d	c	-2
3b	62	Orange	2 4 2 2 1 1	1 3 1 1 3 1 1 1	1 3 2 1 2 2 1 1	d- d- d	c-	-3
4a	88	Yellow	1 4 2 4 1 1	1 3 3 3 2 1	1 2 4 2 2 2	c- d d	b-	-3
4b	87	Yellow	4 3 1 4 2	5 2 2 3	6 2 1 2	c c c	b-	-1
5a	28	Green	1 2 2 2 1 4	1 3 2 1 1 1 4	1 1 4 1 1 1 1 3	d- d c-	f	4
5b	47	Green	1 5 3 1 2 3	1 3 2 1 1 1 3	1 4 2 1 1 1 3	c- c- c-	d-	3
5c	52	Green	2 3 3 2 2 1	1 4 3 2 2 1	4 2 2 2 2 1	b- c c	d	5
6a	21	Blue-green	1 4 1 1 1 2 1 1	2 2 1 2 1 2 1 1	1 1 3 1 1 1 1 3 1	e e e	g	5
6b	28	Blue-green	3 3 1 1 1 3 2	2 2 1 2 1 2 3 1	1 1 3 1 2 3 1	d- d c-	f	4
7a	10	Blue	1 3 3 1 1 4	1 1 2 3 1 1 3	1 2 2 3 3 1	g f- c-	i	6
7b	38	Blue	1 1 5 1 3 2 1	2 1 3 2 1 1 3 1	2 2 3 1 3 2 1	c- c- c	e	4
8a	19	Violet	2 4 1 1 4 1	2 3 1 1 1 4	1 2 3 1 1 5	d- e d-	g	8
8b	11	Violet	1 4 3 1 4	1 3 3 1 1 4	1 2 4 1 1 4	f- f- f	h-	6
9	30	Red	2 2 3 1 3 1	2 2 3 1 1 1 2 1	3 2 2 1 1 1 2	d- e d	e-	3
10	35	Green	2 2 3 2 1 3 1 1	3 1 1 4 4 1 1	3 2 1 1 4 1 1	e- e- e-	e	-1
11	1	Blue	9 6	9 6	8 6	i i i	i-	1
12	68	Orange-yellow	2 1 1 4 1 2 1 1	1 3 1 1 2 3 1 1	1 4 1 2 3 1 1	e e e	c	-5
13	13	Blue-green	1 6 1 1 3 2	2 5 1 2 1 2 2	2 1 4 1 2 2 3	e- e e-	h	8
14	22	Purple	2 6 3 1 1	2 6 1 1 3	1 2 3 1 1 1 1 3	e- e- c-	f-	3

contrast or clearness of the colored and uncolored pictures are equal for any given brightness of the uncolored light, for all values of brightness of the uncolored light less than this, the colored picture will seem to have greater contrast or clearness.

The columns under "Average" in the Table give the average brightness, clearness and contrast of all the observers for both trials, the two trials being weighed equally though there were more observers at the first than at the second. The second trial, as may be seen, indicates a value of brightness, clearness and contrast lower than the first by approximately 20%, 15% and 30%. Part at least



Units of B-T arranged in a circular spectrum.

of this difference can be accounted for by a difference in the two machines (which were interchanged for the second trial) so small as to be detectable only by the averaging of a number of readings such as those described.

As far as can be seen clearness and contrast follow brightness quite closely, instead of contrast being considerably greater in the colored picture, as reported in the last Transactions. This would lend some strength to the belief that dye does not act uniformly on

a photographic film having different quantities of silver at different points, but that the dye collects around the silver particles.

In the column headed "Transmission" are given the values graded by letter of the transmission fraction given in the second column, and under B-T the difference between the average brightness, as judged by the picture on the screen, and the transmission—i. e., the brightness as measured by the flicker photometer. The units are approximately 10% of the larger value (one-third the difference between any letter and the next in order). These values of the differences are shown very roughly in the accompanying figure. The spectrum is arranged in a circle, the ends being brought together so that the violet fades into the red as the red fades into the orange.

Though far from perfect in their agreement, the points indicate a fourfold difference of brightness as compared on the screen between yellow and violet of equal brightness as measured by the flicker photometer. Also there seems to be a suggestive symmetry about the orange-yellow, blue-violet diameter.

In conclusion, the Committee wishes to show a few representative slides to indicate not only the method of the experiments, but also the difficulty an observer experiences in determining the effect of color on brightness, as well as clearness and contrast. Though in some instances the preference is quite marked it does not necessarily follow, as is shown in the Table, that a second trial of the same slide will produce the same impression.

The Committee does not regard the conclusions indicated above as in any sense final, but the problem is one of such complexity, and the time available for the tests so short, that progress must necessarily be slow.

W. E. Story, *Acting Chairman.*

Reducing the Fire Hazard in Film Exchanges

By George A. Blair

WITH the rapid growth of the use of motion pictures in the amusement, educational and scientific fields, there has been a corresponding increase in the amount of film in storage and commercial circulation, and while regulations were adopted with respect to transportation and safeguards including the use of fire-proof booths and licensed operators in its projection in the theatres, comparatively little attention was given to the matter of proper and adequate protection in the ever increasing number of film exchanges, from which distribution is made to the motion picture theatres.

This situation, as far as the exchanges are concerned and particularly in the earlier days of the industry, may be attributed to the necessity of securing convenient and available premises, without sufficient consideration being given to the fact that the storage of film introduced a fire hazard, more especially where large quantities of naked film were being handled.

A relatively small number of the many connected with the motion picture industry in its various branches are familiar with the manufacture of the film or have understanding of its physical properties, more especially with respect to its behavior when subjected to fire. Under the circumstances, it will be recognized that carelessness and indifference in the handling were constantly in evidence, yet in spite of this condition serious fires with attendant loss of life were a comparatively rare occurence.

Practically all motion picture film used in the amusement or theatrical field has a nitro-cellulose base or support on which the sensitive or photographic emulsion is coated. This base or support is composed of a cellulose nitrate of a low degree of nitration. It is readily inflammable and one of its interesting characteristics is that, chemically speaking, sufficient oxygen is present within the structure of the material to help support combustion, or to continue decomposition without additional outside air.

When ignited and burning in a liberal supply of air, film burns rapidly with a yellow flame and very little smoke, but if there is a limited supply of air it will often decompose without flame but with the evolution of a dense, whitish-yellow gas, which latter phenomenon is called decomposition.

One of the first serious film fires occurred on September 7, 1909, in a film exchange located in the Ferguson Building, Pittsburgh, where the breaking of an unprotected extension electric light bulb set fire to a naked reel of film within a vault which contained about 185 reels. The burning reel was thrown out of the vault to an adjoining room and the door closed but other reels within the vault became ignited. There was no vent or pressure relief leading out of the vault, so that the gases of decomposition were formed

under pressure and forced out around the door cracks to adjacent rooms. The mixture of gases with the air caused a violent explosion in these rooms, while the vault remained intact with the door closed. On later investigation it was found that the reels within the vault had undergone decomposition, leaving only a carbonacious skeleton which retained very closely the original form of the rolls.

This unusual explosion called for an immediate and thorough investigation. Since the action of the fire and methods of combatting it were not understood, an almost exaggerated fear of the hazard involved in this type of business was created.

As part of this investigation, a study of the nature of the gases of decomposition was made by the Explosive Division of the United States Geological Survey. The result substantiated previous investigations made of the flameless decomposition of celluloid; namely, that the gases consist of variable quantities of such gases as carbon monoxide, carbon dioxide, hydrogen, nitrogen, oxygen, N_2O_4 and N_2O_5 together with tarry matter. It was found that if decomposition occurred under pressure, the percentage of hydrogen and carbon monoxide was high, thus giving a greater probability of an explosive gas mixture with air. Under ordinary pressure, however, the hydrogen and carbon monoxide are present in lower percentages. It was then first realized that a pressure relief opening is absolutely necessary in storage vaults, and that any explosions which may occur in connection with the storage of film are gas explosions. Motion picture film itself, contrary to an erroneous popular idea, does not and will not explode. Its danger lies in its proclivity to decompose at a temperature slightly over 300° F. and to continue decomposition without the aid of oxygen from the air.

The need for standard and effective means for the prevention and combatting of film fires was seen. No general attempt had previously been made to draft regulations for governing the handling and storage of inflammable motion picture film. As aforestated, there had been but few fires with an extremely small loss of life, but the hazard was recognized, and the Spring of 1915 saw the beginning of experimental tests which were to serve as a basis for future standards of fire protection for film.

The test at the Universal Film Manufacturing Company plant at Fort Lee, N. J., to determine the proper size of vent for film storage was immediately followed by a series of tests conducted by the Eastman Kodak Company to ascertain the effectiveness of automative sprinkler protection in vaults, and proper methods of storing film.

The details of these tests are of interest, but it is probably more advisable at this time to give merely the results, which may be briefly summarized as follows:

> *First:* Automatic sprinkler protection is absolutely essential in film storage vaults and cabinets. Each standard vault of 750 cubic feet should be equipped with 12 sprinkler heads, for only large quantities of water instantly applied can provide the

necessary cooling effects and prevent the possible formation of explosive gas mixtures.

Second: Ample pressure relief openings or vents are necessary to prevent the building up of pressure in vaults and cabinets. The area of these vents was determined at 70 square inches for each 100 reels of film or at 1,400 square inches for each standard vault of 750 cubic feet, actual storage capacity.

Third: The subdivision of the film racks into sections by asbestos board or heat insulating material is an added safeguard, or check, to the rapid spread of fire.

Fourth: All film, whether in vaults or in rooms, should be kept in individual containers made of a heat resistive material, and with corrugated top and bottom. These containers are round; about 10½″ in diameter and 1¾″ thick.

Fifth: These individual containers must be stored on edge, that is, in a vertical position. This will insure proper sprinkler operation, the corrugations permitting the free passage of water between the containers, thus checking the spread of the fire.

Sixth: All film, when not actually being worked upon, should be kept in storage vaults or cabinets.

With the results of these experiments as a basis, and with the knowledge and conviction that motion picture film fires could be controlled, the National Fire Protection Association drew up regulations governing the handling and storage of nitro-cellulose motion picture film, recommending their adoption as standard. These regulations have undergone but few minor changes and are now published in booklet form by the National Board of Fire Underwriters and recommended by them to be used as a basis for municipal ordinances.

For the most part, such fires as occurred were caused through carelessness and the neglect of precautionary measures and a general lack of understanding as to the proper methods of handling and safeguarding the film.

The motion picture interests, realizing that fire protection was economically advisable and necessary as a matter of safeguarding life and property and that neglect or failure to observe standards of fire protection would have a detrimental reaction on the entire industry, appointed, through their organization—the National Association of the Motion Picture Industry—a special committee on fire prevention.

Another fire, which unfortunately again occurred in a Pittsburgh film exchange on January 7th, 1919, and in which a number of lives were lost, provided a concrete impetus to the carrying on of this new work. The regulations recommended by the Fire Protection authorities were endorsed and the entire association pledged itself to the active improvement of existing conditions in film exchanges throughout the country and to the instruction of those immediately responsible for exchange management.

The Eastman Kodak Company offered assistance in the furtherance of this program by providing men, especially trained for this

particular type of work, who made thorough inspection of every exchange in the United States and Canada, and in each case submitted reports containing positive recommendations for improvement to the producers operating these exchanges. In these tours of inspection, which covered 56 cities, approximately 1,500 inspections were made in about 600 different exchanges. Each exchange received at least two visits and most of them were inspected three times. That there was great need for better methods of fire prevention in all localities was forcibly demonstrated, and, also, that to provide adequate protection in these exchanges, the majority of which had substandard equipment and were improperly housed, would require a wasteful and unsatisfactory program of expenditure. This situation being drawn to its attention, the National Association of the Motion Picture Industry entered upon a broader plan of constructive activity and, through its film exchange building committee, has been actively engaged in promoting the erection of new and adequate film buildings, complying fully with the fire prevention regulations and providing ideal arrangements for the conducting of an exchange business.

As a direct result of this work, buildings in Kansas City, Atlanta, Pittsburgh, Buffalo and Cincinnati have been completed and are occupied exclusively by film exchanges, and exchange buildings are in the course of construction in Cleveland, New Haven, Omaha, Montreal, San Francisco and Los Angeles, while active promotion is being carried on in Philadelphia, Chicago, Milwaukee, St. Louis, Indianapolis, Denver, Salt Lake City and other cities.

At a regularly called meeting of the Distributors' Division of the National Association of the Motion Picture Industry held in New York on April 23rd, 1920, the following resolution was passed:

> *Resolved,* That we affirm our pledge of cooperation with and support of the work of the National Fire Protection Association and the recommendations of that body for the handling and storage of motion picture film as adopted by the National Board of Fire Underwriters.

This resolution, together with a report of the activities of the Fire Prevention Committee, was read at the 24th Annual convention of the National Fire Protection Association held in Chicago on May 4th, 5th and 6th, 1920, and was received with unqualified approval by that body.

In connection with the new Kansas City building referred to, undoubtedly most of you have learned of the recent fire in this building. After a thorough investigation had been made, it was conclusively shown that the fire was entirely due to violation of minor structural details and, most important of all, to the absence of automatic sprinkler protection, which was in course of installation at the time of the fire. Had it not been for the major structural features of the building, which proved their worth in an excellent manner, the results would in all probability have been much more serious. The fire was confined to a very small portion of the

eleventh and twelfth floors, being held by fire doors and partitions. The damage to the building was almost inconsequential, or in the neighborhood of $10,000.00.

The Eastman Kodak Company stands ready and willing at all times to act in an advisory capacity on plans and specifications of prospective film exchange buildings without cost to the builders; also to make inspection of buildings as construction progresses and prior to occupancy, and should it be found that the plans as recommended have not been followed, to point out the facts in written report to both owners and lessees.

It is believed that with such cooperation. the exchanges will be properly constructed and equipped and, with the addition of good housekeeping and maintenance on the part of the tenants, that the possibilities of fires will be reduced to the minimum with absolute certainty of quick control, should they, by any chance occur.

Reflection Characteristics of Projection Screens

By Lloyd A. Jones and Milton F. Fillius

When it is considered that the enjoyment of the entertainment offered in the motion picture theater depends almost entirely upon the visual organs, it will be recognized that the importance of providing conditions which will result in the least possible visual fatigue to the audience cannot be overestimated. There are many factors which deserve the consideration of the motion picture engineer in order that the maximum of visual comfort may be obtained, among which may be mentioned the proper distribution of the interior illumination, the elimination of excessively bright surfaces in the field of vision, and the proper adjustment of the screen brightness. The fact that the attention of the audience must remain fixed for long periods of time upon the projected picture makes it of utmost importance that the projecting system be so adjusted that the screen brightness is neither so high as to cause visual fatigue due to glare, nor so low as to throw an undue burden upon the retinal accommodation.

The optical properties of the surface upon which the motion picture is projected determines to a great extent the ultimate efficiency of the entire installation, and hence should receive due consideration at the hands of the motion picture engineer. While there is no doubt that this is recognized, and that considerable improvement in the quality of projection screens has been made in recent years, it seems that the subject has been approached largely from the practical standpoint and that little quantitative data are available relative to the optical characteristics of the materials used so extensively at the present time.

In view of this deficiency, it seemed worth while to examine critically the reflection properties of the large number of commercial screens on the market. From the data obtained by such examination, it will be a relatively simple matter to choose the most efficient screen surface for a given installation. An examination of the commercial screens obtained showed a remarkable variation in reflection characteristics, ranging from surfaces which almost completely diffuse the incident light to screens of a very specular nature, having very high reflecting powers on the projection axis and very low values in directions departing by relatively small amounts from the normal. When the question of adapting the screen to the shape of the room in which it is to be used is considered, it will be seen that it is quite hopeless to obtain in all cases the maximum efficiency with a screen of fixed characteristics.

For instance, if the length of the room is large relative to its width, a screen of the completely diffusing type is very wasteful of light, and the necessary screen brightness can be obtained over the required angle by the use of a screen which reflects a large proportion of the incident light within a comparatively narrow angle,

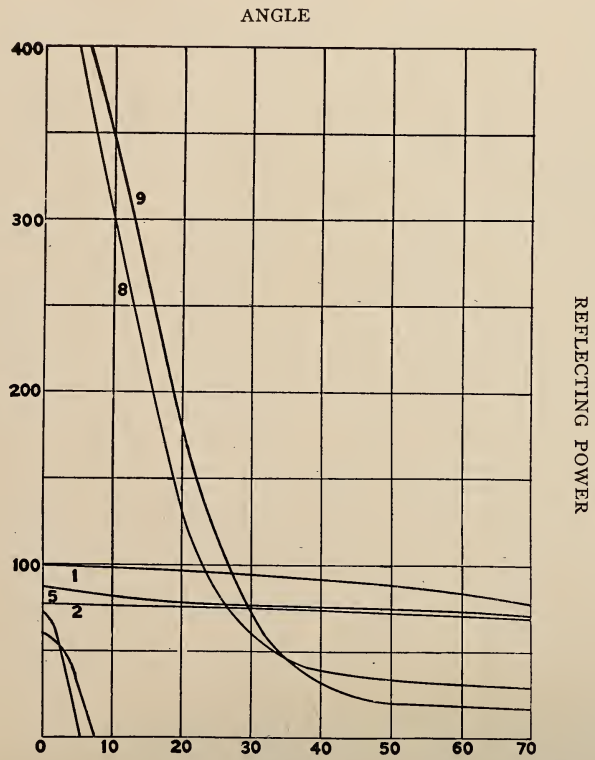


Fig. 3. Distribution Curves of Miscellaneous Surfaces.

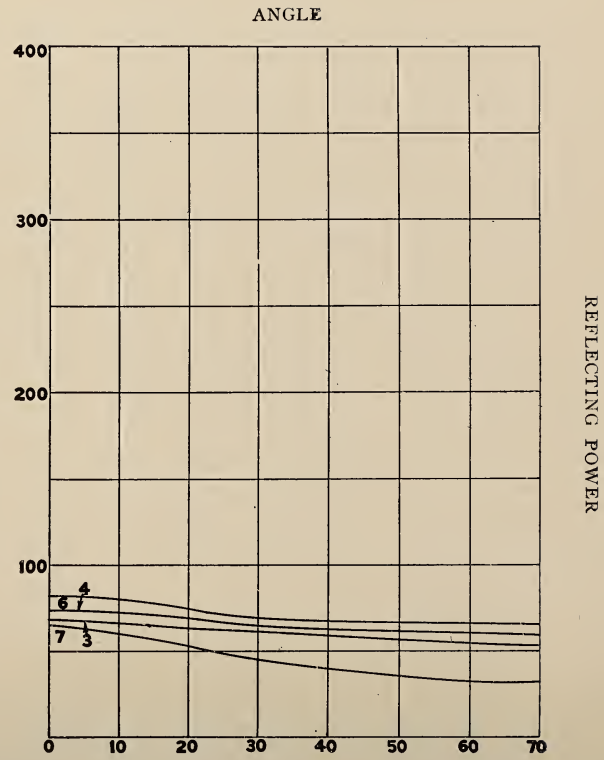


Fig. 4. Distribution Curves of Miscellaneous Surfaces.

thus permitting the use of lower amperage in the arc of the projection machine. On the other hand, a screen of the specular type installed in a room where the length is relatively small as compared with the width will not be found satisfactory. Since the screen in this case may be viewed by a part of the audience at a relatively large

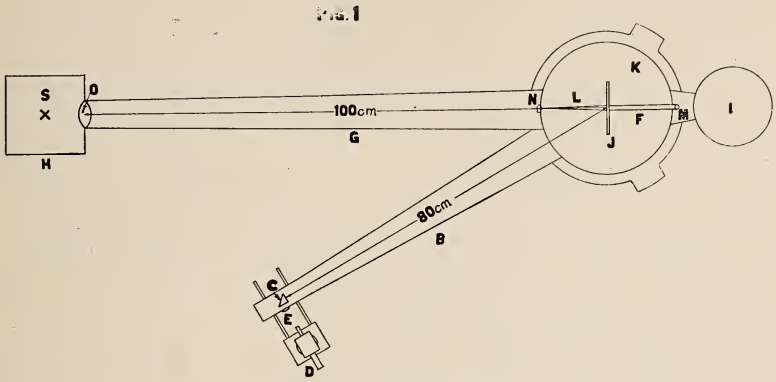


Diagram of Goniophotometer.

angle, it will be necessary to use a high arc current in order to make the picture of satisfactory brightness for these observers. This will result in an unnecessarily high brightness on the axis of projection and may result in excessive visual fatigue owing to glare. It should be pointed out also in case the throw is somewhat short that a highly

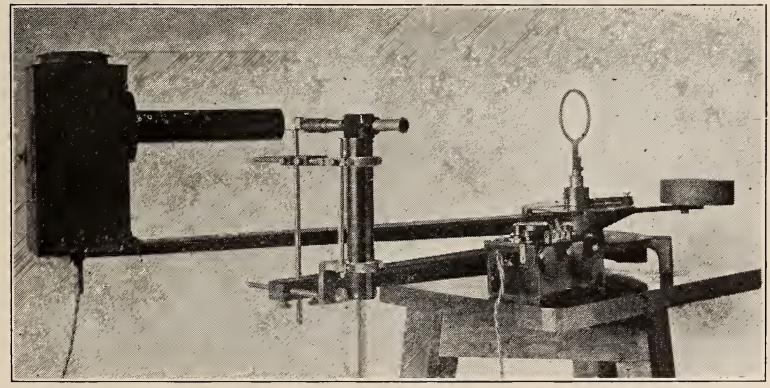


Fig. 2—Photograph of Goniophotometer.

specular screen may appear of unequal brightness when viewed from a single point of observation, since the angle of incidence varies from point to point on the screen, and that for an observer relatively near to the screen the angle of observation is not constant for all parts of the picture.

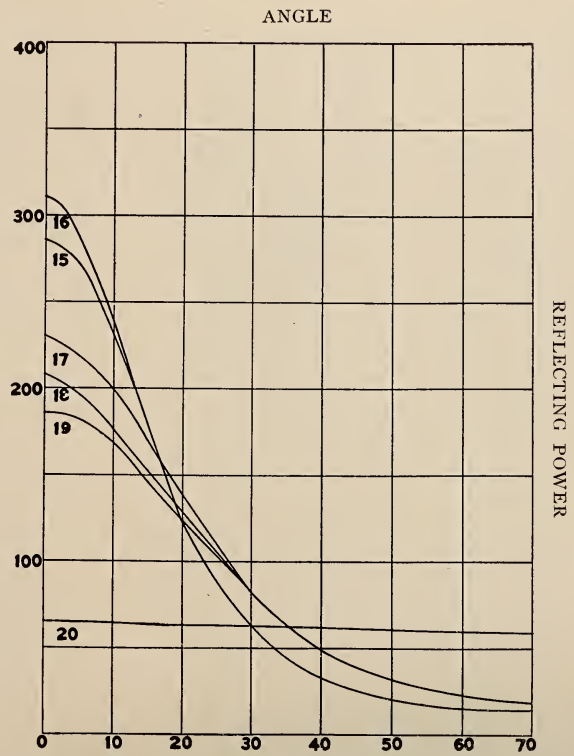


Fig. 5. Distribution Curves of Commercial Projection Screens.

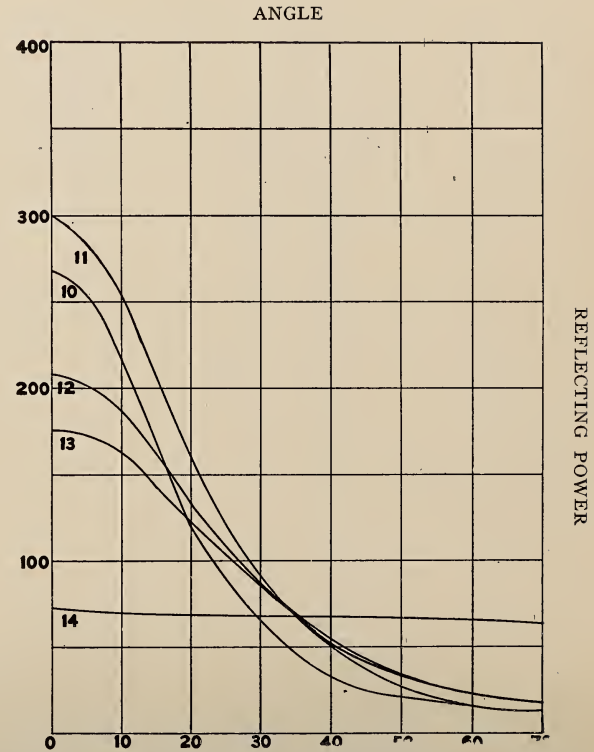


Fig. 6. Distribution Curves of Commercial Projection Screens.

The problem of measuring and specifying the characteristics of diffusing surfaces has been treated by Dr. Nutting[1] and results on several characteristic surfaces are given. The data given, however, relate almost entirely to miscellaneous surfaces, only two commercial screens being included among the materials examined by him. Recently a paper by Charles W. Gamble[2] has appeared in which he deals with the subject in a more or less general way. Here again the data given relate largely to surfaces which are not extensively used in the motion picture theatre. His results are of a qualitative character and the highest efficiency obtained is that of a mirror ground on the front surface.

Method and Apparatus

The method adopted in this investigation is quite similar to that used by other investigators and consists in measuring the brightness of the surface under examination when viewed at various angles of observation, the illumination being incident normally upon the screen surface. The incident illumination in this case was approximately parallel light, such conditions being considered as more closely approaching those existing in practice than the method used by Dr. Nutting in which case a completely diffused source subtending 1/10 of a steradian at the surface was used. In order to expedite the experimental work which involved the examination of a large number of samples, a special goniophotometer was constructed. A diagram showing the essential parts of this instrument is shown in Fig. 1.

A heavy cast-iron base, *A*, supports the arm *B*, at the end of which is carried the photometric apparatus. In order that the observer and the photometric equipment might not interfere with the illumination of the sample at angles approaching closely to the normal, the axis of observation was bent at right angles by use of the total reflecting prism C. A portable photometer of the illuminometer type was mounted at *D*, and the small lens *E* placed immediately in front of this photometer permitted the formation of an image of the surface under examination in the plane of the photometer cube. In case the texture of the surface was such as to interfere with precise photometric settings, this lens could be displaced by amounts sufficient to eliminate the disagreeable surface texture. A rigid bearing *E* supported by the base casting carries a movable arm *G* on one end of which is mounted the lamp house *H*, while at the other end a counterpoise weight *I* is placed. A holder is provided for the sample at *J*, this is so mounted that it holds the surface of the samples being examined in the plane passing through the axis of rotation of the arm *G*. The circular scale plate *K* is mounted in a fixed position relative to base *A*. A pointer attached to the sample

[1]Nutting, P. G., Trans. Ill. Eng. Soc., Vol. II: 1916, p. 92.

[2]Gamble, Charles, W. B., B. J., Vol. LXVII, 1920, p. 553.

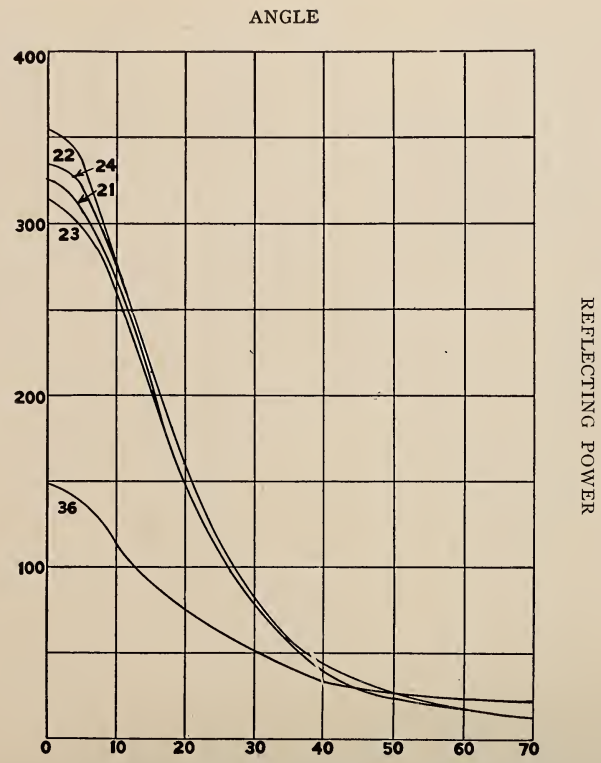


Fig. 7. Distribution Curves of Commercial Projection Screens.

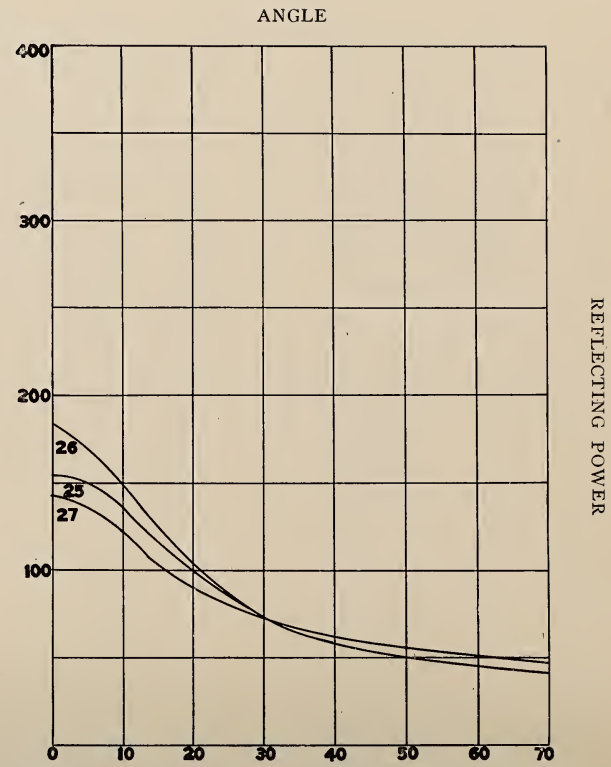


Fig. 8. Distribution Curves of Commercial Projection Screens.

holder indicates the angle on the divided circle. By means of a pin *M*, the sample holder can be connected rigidly with the moving arm *G*, so that the plane of the sample will remain perpendicular to the incident illumination for all positions, and as the arm *G* is rotated the angle of observation alone varies. This provides for the measurement of the surface brightness at various angles of observation and fixed direction of illumination. By removing the pin *M* and clamping the sample holder to the base, *A*, the arm *G* moves independently of the sample, and observations of brightness at a fixed angle of observation, but with a variable angle of incidence can be made. In the front of the lamp house is mounted a lens *O* of such focal length that the source *S* falls at its focus. Under such conditions the light incident on the sample is approximately parallel. The dimensions of importance are as indicated in the figure. It is also so arranged that the lens *O* can be removed and in its place substituted a disk of diffusing material such as ground pot opal glass.

The dimensions are so adjusted that the effective area of this diffusing material is just sufficient to subtend an angle of 0.1 steradians at the surface of the sample under examination. A 500-watt Mazda C lamp of the concentrated filament type was used as a source for illuminating the samples. A photograph of the apparatus is shown in Fig. 2. The voltage was precisely controlled in order to eliminate variations in brightness due to fluctuations in the line voltage. Brightness measurements were made at angles of observation from 0 to 70°. Three complete sets of readings were made by two observers on each screen, and the final result obtained by taking the average of all readings. In practically all cases excellent agreement between the individual sets of data was obtained.

The results are expressed in terms of the reflecting power of magnesium carbonate with normal illumination and observation as 100%. The absolute value of the reflecting power of magnesium carbonate is at the present time subject to some question and in view of that fact it was not deemed advisable to attempt to reduce the measurements of screen reflecting powers to absolute terms. The values given are therefore relative to that of magnesium carbonate. When a satisfactory value for this material is determined that data can then be reduced to absolute terms, if such seems desirable.

Materials Examined

Orders for samples of the commercial projection screens were placed with practically every maker whose advertisement could be located in the trade journals. Response was not obtained from all makers, but a fairly representative group of samples was received. The standard samples were prepared by mounting a piece of the projection screen 8 inches square on a thin metal plate, thus insuring flatness of the sample under examination. In addition to the commercial screens mentioned, several miscellaneous surfaces of interest were examined.

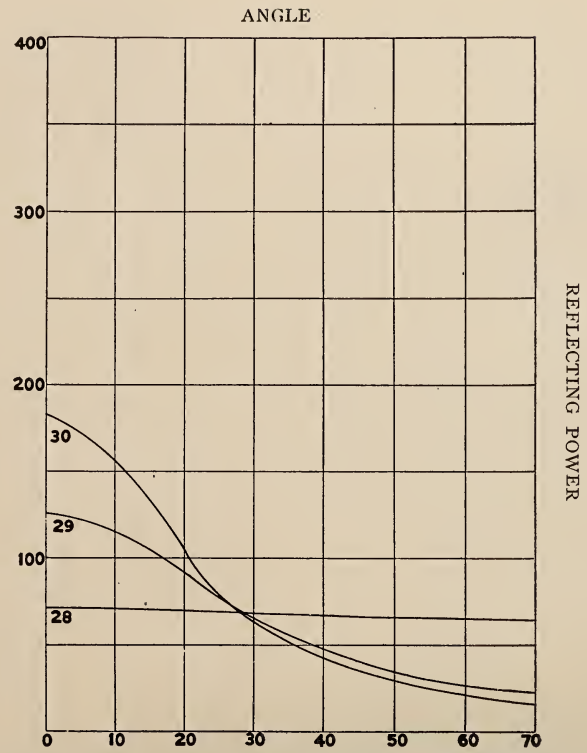


Fig. 9. Distribution Curves of Commercial Projection Screens.

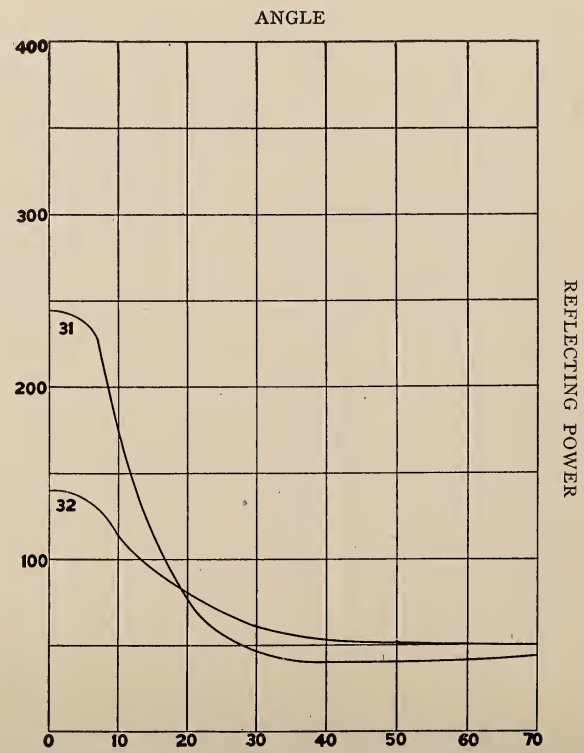


Fig. 10. Distribution Curves of Commercial Projection Screens.

TABLE 1

No.	Class	Name	Texture	Color
1	C	Magnesium Carbonate	Smooth	White
2	C	Opal Glass	Smooth	White
3	C	White Blotting Paper	Smooth	White
4	C	Photo Stock Plain	Smooth	White
5	C	Photo Stock Coated	Smooth	White
6	C	White Drawing Paper	Smooth	White
7	B	Sandblasted Aluminum	Smooth	Metallic White
8	A	Sandblasted Mirror	Smooth	White
9	A	Focus Screen and Mirror	Smooth	White
10	A	Superlite	Coarse Grain	Metallic White
11	A	Special	Coarse Grain	Metallic White
12	B	Green Back	Fine Grain	Metallic White
13	B	White Back	Fine Grain	Metallic White
14	C	Plain White Coated	Smooth	Yellow
15	A	Imsco Silver No. 1	Coarse Grain	Metallic White
16	A	Imsco Gold No. 1	Coarse Grain	Metallic Yellow
17	A	Imsco No. 2	Coarse Grain	Metallic White
18	A	Imsco No. 3	Medium Grain	Metallic White
19	B	Imsco No. 4	Fine Grain	Metallic White
20	C	Imsco White Muslin	Smooth	White
21	A	Minusa A	Medium Grain	Metallic White
22	A	Minusa B	Coarse Grain	Metallic White
23	A	Minusa C	Coarse Grain	Metallic White
24	A	Mazda-Lite	Fine Grain	Metallic White
25	B	Idealite-Grade 1A	Fine Grain	Metallic White
26	B	Idealite-Grade 1B	Medium Grain	Metallic White
27	B	Idealite-Grade 2	Fine Grain	Metallic White
28	C	Dalite Crystal White	Smooth	Blue Green
29	B	Dalite Gold Fibre	Fine Grain	Metallic Yellow
30	A	Dalite Silver	Fine Grain	Metallic White
31	A	Argus Crystal Bead No. 1	Medium Glass Beads	Yellow
32	B	Argus Crystal Bead No. 2	Fine Glass Beads	Yellow
33	B	Mirroroid	Fine Grain	Metallic White
34	A	Gold Ring	Smooth	Metallic Yellow
35	C	Half-tone	Smooth	White
36	A	Aluminium Paper	Smooth	Metallic White

In Table I is given a complete list of the materials measured.

The surface of the magnesium carbonate sample (1) was prepared by carefully scraping a block of the material with a steel straight-edge. The opal glass (2) was of the best quality obtainable for uniformity and whiteness, and the surface was carefully ground. The white blotting paper (3) was of the ordinary commercial quality used extensively in photographic work. The photographic stock (4) was a sample of uncalendered and uncoated material. No. 5 was of the same material but treated with the ordinary baryta coating. The drawing paper (6) was the commercial grade of Wattman's hot pressed. Sample No. 7 was prepared by sandblasting a sheet of aluminum. No. 8 was made by sandblasting the front surface of an ordinary plate glass mirror. No. 9 consists of a screen made by superposing a sample of the material such as is commonly used as the focusing screen in photographic apparatus upon the surface of an ordinary plate glass mirror.

The commercial screens examined are also listed in Table 1, beginning with sample No. 10. In the name column is given the trade name applied by the manufacturer to the screen. In the "texture" column is a qualitative statement of the character of the surface, while in the "color" column is a qualitative statement of the color. The terms used in specifying texture and color are very general in nature, no precise quantitative measurements being made of these

characteristics. An examination of the characteristics of these screens shows that they can be roughly grouped into three general classes which may be specified as follows: Included in Class C are those screens which give almost complete diffusion of the incident light. Class A includes those which reflect a large proportion of the incident light within a very narrow angle, and very little light at the greater angles. Class B includes the screens which are intermediate between the extremes represented by Classes A and B. It should be understood that the line of demarkation between these three classes is not distinct but that such classification is entirely arbitrary and made only for the purpose of practical convenience.

TABLE 2

MISCELLANEOUS SURFACES

No.	ANGLE									
	0	5	10	15	20	30	40	50	60	70
1	100	100	99.9	98.0	96.9	94.9	92.4	89.5	84.8	78.8
2	77.1	77.1	76.0	76.0	74.8	73.7	73.7	72.6	70.5	68.2
3	68.9	67.9	65.9	64.0	63.0	60.8	59.7	57.2	54.8	54.2
4	73.9	73.9	71.2	70.0	67.0	65.0	63.5	62.2	61.1	58.4
5	91.1	88.0	84.9	82.5	80.5	79.3	78.7	78.7	76.9	74.3
6	82.7	82.7	81.5	77.8	74.4	72.0	69.5	63.3	67.6	65.4
7	66.3	64.1	61.4	57.6	52.4	46.5	40.1	36.0	35.3	32.6
8	473	399	297	224	121	62.0	40.2	34.2	32.0	31.1
9	460	430	373	257	176	73.3	31.9	20.5	19.0	19.4

The names specular, semi-diffuse, and diffuse may conveniently be applied in the classes A, B, and C, respectively. The indication of the class to which each screen belongs is given by the letter in the "Class" column of Table 1.

Results

In Table 2 are given the reflecting powers at the various angles of the miscellaneous surfaces examined, while in Table 3 are the detailed data relative to the reflection characteristics of the twenty-seven commercial screens examined. In order to present these data in more graphic form they are plotted as curves in the following figures, the ordinates in all cases being values of relative reflecting powers and the abscissae the angles of observation to which the various reflecting powers apply.

The sample to which the curve applies is in all cases indicated by attaching the sample number. In Figure 3 are given the curves for the mirror with the sandblasted surface, and with superposed focusing screen. It will be noted that the values at normal observation are extremely high, but that the values diminish very rapidly as the angle of observation increases. Curves for samples Nos. 1, 2, and 5 are also given in this figure.

In Figure 4 are given the curves for some of the almost completely diffusing miscellaneous samples.

In Figure 5 are the curves relating to the screens manufactured by C. S. Wertsner and Son. It will be noted that among these are found examples of all three classes.

In Figure 6 are the curves relative to the screens manufactured by the Independent Movie Supply Co. and here again we find examples of all three classes.

In Figure 7 are given the curves relative to the Minusa Cine Screens and to one of aluminum coated paper manufactured by W. G. Preddy, this latter is of the semi-diffusing type.

In Figure 8 are the curves for the Idealite screens manufactured

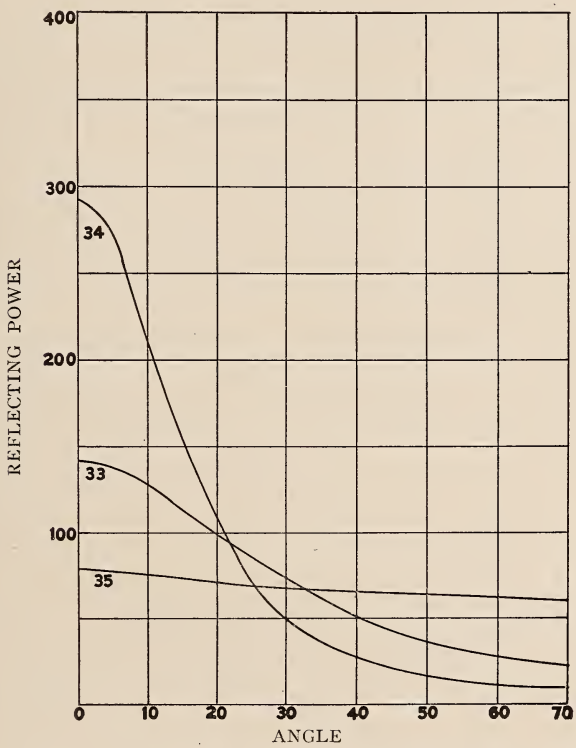


Fig. 11. Distribution Curves of Commercial Projection Screens.

by the Ludeke Screen Company. All of these fall in the semi-diffusing class.

In Figure 9 are the curves for the screens manufactured by the De Berri Screen Company, two of which are of the semi-diffusing type, while one is of the diffusing type.

In Figure 10 are the curves of the Argus Crystal Bead Screens, one of which is of the specular type and one of the semi-diffuse type. These screens are made by covering a surface of fabric with small glass beads. The reflection curves are peculiar in that the reflecting

power at 5° is but very little less than that at 0, giving a distribution curve much flatter near the normal than is usual with screens of that type.

In Figure 11 are the curves for samples Nos. 33, manufactured by H. C. Genter & Company; 34, by the Gold King Screen Company; and 35, manufactured by A. L. Raven. In this figure one screen of each class is represented.

Analysis of Results

In order to facilitate the examination of the data, it will be well to separate them into their respective classes. After careful consideration of the characteristics of the screens and of the requirements of practical use, it was decided to define the range covered by these classes as follows:

Class A includes those screens which are adapted for use in theatres where the maximum angle of observation does not exceed 30°; Class B includes the screens adapted for use where the maximum angle of observation does not exceed 50°, while the Class C screens should be used in all cases where the angle of observation is greater than 50°. The point should be again emphasized that these classifications are not rigid, but of an approximate character.

After careful consideration of the subject, it was decided that the value of the ratio of the reflecting power measured at normal observation to that measured at the maximum angle of observation

TABLE 3

COMMERCIAL SCREENS

10	268	256	215	168	120	64.8	34.3	21.8	16.8	14.2
11	300	284	255	206	167	93.9	52.2	26.5	17.0	13.3
12	208	203	188	161	134	85.0	53.3	33.0	22.4	18.3
13	177	174	165	143	122	85.9	53.0	33.0	23.8	17.7
14	72.9	72.2	70.8	70.5	69.4	68.9	68.1	68.8	67.0	64.0
15	286	273	229	173	129	66.0	33.0	21.4	15.2	13.7
16	311	288	234	180	125	66.0	35.0	21.7	15.6	14.0
17	230	220	200	171	141	83.1	47.4	29.6	20.3	16.0
18	208	197	177	152	127	80.6	47.9	34.3	24.3	19.9
19	186	183	169	146	120	79.8	47.9	31.3	22.2	17.6
20	66.4	66.3	65.2	63.6	62.4	61.0	60.4	60.0	59.3	58.9
21	326	308	270	204	157	76.0	38.6	25.7	15.0	12.6
22	355	339	274	207	149	71.7	35.8	21.7	15.0	12.8
23	315	298	256	203	151	77.9	38.9	23.0	16.1	13.0
24	334	323	276	215	160	82.9	40.0	24.5	16.6	13.8
25	154	151	136	112	97.0	75.1	56.0	52.9	47.0	43.0
26	193	187	154	124	98.5	72.2	58.4	50.2	45.2	40.9
27	142	137	122	103	93.6	76.4	63.7	55.6	50.8	46.8
28	71.7	71.7	70.8	69.9	69.2	68.6	67.1	66.0	65.3	64.8
29	126	120	116	104	90.7	68.8	47.1	34.3	26.5	21.9
30	183	172	157	134	107	65.0	42.1	28.8	20.9	16.8
31	244	240	177	116	75.6	45.5	40.0	39.6	41.7	43.7
32	140	138	113	91.4	78.6	60.9	54.8	50.8	50.4	50.0
33	142	138	129	109	99.0	73.4	49.5	35.7	27.4	22.5
34	292	271	216	160	108	49.2	28.4	17.4	13.1	9.7
35	78.6	78.6	74.9	73.3	71.1	68.6	65.3	63.9	62.3	59.5
36	148	136	111	93.6	74.1	50.2	34.1	26.5	22.6	19.5

in a particular installation would serve as the most logical criterion by which to select the most suitable screen for that particular case.

This value will then represent the ratio of the brightness of the screen as observed by a person in the center of the auditorium to that of the brightness as observed by a person occupying a seat at the side and near the front. Be keeping this ratio below a certain limiting value, satisfactory brightness will be obtained for all observers. This factor alone, however, is not sufficient for the classifying of screens according to their relative merits. The highest average reflecting power within the required angle from the normal will necessitate the least energy expenditure in the projecting system to produce a given screen brightness.

Assuming cases in which the maximum angles of observation are 20°, 30°, 40°, and 50° the values of the ratio of the reflecting power at normal observation to that at these various angles were computed for all screens and likewise values of mean reflecting

TABLE 4

CLASS A

No.	20°		30°		40°		50°	
	$\frac{R_o}{R_{20}}$	R_a	$\frac{R_o}{R_{30}}$	R_a	$\frac{R_o}{R_{40}}$	R_a	$\frac{R_o}{R_{50}}$	R_a
8	3.91	305	7.62	235	11.8	194	13.8	165
9	2.61	339	6.30	270	14.4	217	22.4	183
34	2.70	209	5.94	167	10.3	137	16.8	116
31	3.22	159	5.48	127	6.10	108	6.17	96
22	2.38	265	4.96	216	9.92	167	16.3	151
15	2.21	218	4.34	178	8.70	147	13.4	134
21	2.06	253	4.30	207	8.47	172	13.2	145
10	2.23	205	4.14	169	7.82	140	12.3	119
24	2.08	253	4.02	209	8.35	174	13.6	147
23	2.08	245	4.00	201	8.10	167	13.7	141
11	1.80	242	3.20	204	5.75	172	11.3	147
16	1.69	228	3.20	184	6.03	152	9.75	130
36	2.00	112	2.96	96.4	4.34	83.3	5.59	73.2
30	1.70	151	2.82	128	4.35	110	6.36	87
17	1.63	192	2.77	165	4.85	141	7.77	121
18	1.64	172	2.58	150	4.25	128	6.07	112

power for the same limiting angles. These values are tabulated for the Class A screens in Table 4, those for the Class B screens in Table 5, and those for the Class C screens in Table 6.

Now it seems reasonable to demand that the ratio of the brightness on the axis to that at the extreme angle of observation shall not be greater than 4.0. This value is decided upon after consideration not only of the variation in brightness as observed from various

TABLE 5

CLASS B

No.	20°		30°		40°		50°	
	$\frac{R_o}{R_{20}}$	R_a	$\frac{R_o}{R_{30}}$	R_a	$\frac{R_o}{R_{40}}$	R_a	$\frac{R_o}{R_{50}}$	R_a
12	1.55	179	2.45	155	3.91	135	6.30	117
19	1.55	161	2.34	141	3.88	129	5.95	109
13	1.45	156	2.06	139	3.34	121	5.37	106
33	1.43	123	1.93	111	2.87	99	3.97	88
26	1.96	151	2.67	131	3.30	115	3.70	104
29	1.39	111	1.83	100	2.68	90	3.68	79
25	1.59	130	2.05	115	2.75	104	2.91	94
32	1.78	112	2.30	99	2.56	89	2.76	82
27	1.52	120	1.86	108	2.23	98	2.56	91
7	1.26	60.3	1.42	56.7	1.65	53.5	1.84	50.4

points in the auditorium, but also from a consideration of the fact that from a given point of observation the screen may appear of unequal brightness over its area. The danger of this inequality being serious increases rapidly as the value of the above mentioned ratio in reflecting powers increases. A detailed consideration of the geometry of this problem might make this point more clear, but it is not desired to lengthen this paper to such an extent as to include a complete treatment of the subject. Assuming now that we adopt the value of 4 as the limiting value of the reflecting power ratio, it is possible from the figures in Tables 4 to 6 inclusive to choose the best screen for any one of the cases considered. For instance, assuming that the maximum angle of observation is 20°, it will be noted that all values in the ratio column are less than 4. Therefore from the standpoint of distribution any one of the screens in Class A will be satisfactory for use where the angle of observation does not exceed 20°. In order now to obtain the maximum average brightness within this angle for a minimum current consumption it is only necessary to choose that screen, or screens, which shows the highest

TABLE 6

CLASS C

No.	20°		30°		40°		50°	
	$\frac{R_o}{R_{20}}$	R_{m20}	$\frac{R_o}{R_{30}}$	R_{m30}	$\frac{R_o}{R_{40}}$	R_{m40}	$\frac{R_o}{R_{50}}$	R_{m50}
6	1.10	79.8	1.15	77.7	1.19	76.1	1.30	74.6
35	1.10	75.3	1.14	73.5	1.20	71.7	1.23	70.4
3	1.09	65.8	1.13	64.6	1.15	63.5	1.20	62.5
4	1.10	71.2	1.13	69.6	1.16	68.3	1.19	67.3
5	1.13	85.4	1.15	83.5	1.15	82.7	1.15	82.0
1	1.03	99.[illegible]	1.05	97.9	1.08	96.8	1.12	95.5
14	1.05	71.0	1.06	71.0	1.07	70.0	1.07	67.0
20	1.06	64.0	1.09	64.0	1.10	52.0	1.10	54.0
28	1.02	71.0	1.03	70.0	1.04	70.0	1.07	69.0
2	1.03	77.1	1.05	76.2	1.05	75.6	1.06	75.0

value in the column marked R *a*. Now assuming a maximum angle of 30° we find that the first seven screens are excluded since the ratio of normal to extreme reflecting power is greater than 4. Beginning with No. 11 we may then choose the screens showing the highest average reflecting power for the range 0 to 30°. When the maximum angle of 40° is considered we find no screen in Class A which does not exceed the limiting value of 4 for reflecting power ratio. We therefore turn to Table 5, and there find that all values of the reflecting power ratio are less than 4. We may therefore select from Class B that screen which has the highest reflecting power for the 0-40° range. In case of the 50° limiting angle, three of the Class B screens are automatically excluded, and it is only necessary to select from the remainder the one having the highest average reflecting power for the 0-50° angle.

It should be emphasized that this method of selecting a projection screen recognizes only the reflection characteristics of the screen and further that these are considered only from the standpoint of intensity. In many cases it will be found that several screens are practically of equal value when judged by this criterion. In such cases other considerations such as color, surface texture, durability, and other physical properties may be the deciding factors in the final choice. Many of the screens examined show excellent characteristics and while the screen makers are to be congratulated on many of these screens it is to be hoped that this critical examination of screen characteristics may stimulate them to greater efforts and to the production of even better and more efficient surfaces for this purpose.

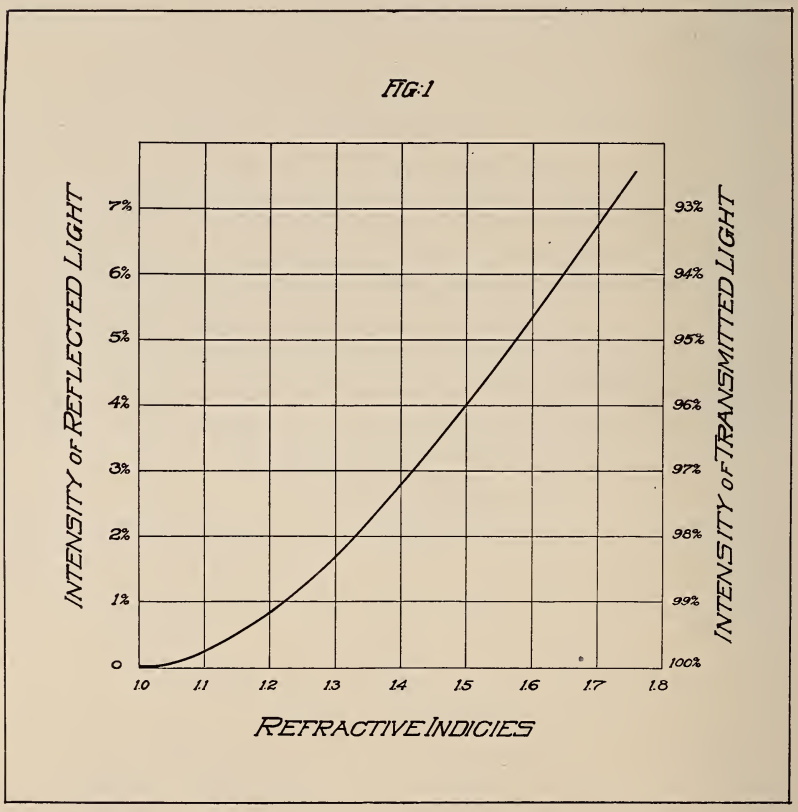
Absorption and Reflection Losses in Motion Picture Objectives

By Hermann Kellner

LOSSES of light in projection lenses may occur for two reasons: First, Geometrical arrangement of power, distances, etc., sizes of lenses;

Second, Physical reasons, material the lenses are made of, conditions of glass surfaces, etc.

It is with the physical conditions that we are concerned with



now. When light strikes a border surface between two optically different media, for instance, water and air, a part of this light enters the water and illuminates the bottom of the containing vessel, while another part is reflected back into the air. So is part of the sunlight which strikes a window passed into the room while another part is reflected upon the street. The ratio of the reflected to the transmitted light depends upon the refractive indices of the media as well as upon the finish of the surface.

The greater the difference in refractive index, the more light is reflected and the less light is transmitted. If we have two horizontal surfaces, side by side, one formed by water, the other one of glass, and observe the amount of sunlight reflected, we will find the glass surface to be a more efficient reflector than the water surface and at the same time the illumination inside the water greater than inside the glass.

The amount of reflected light changes also with the angle of

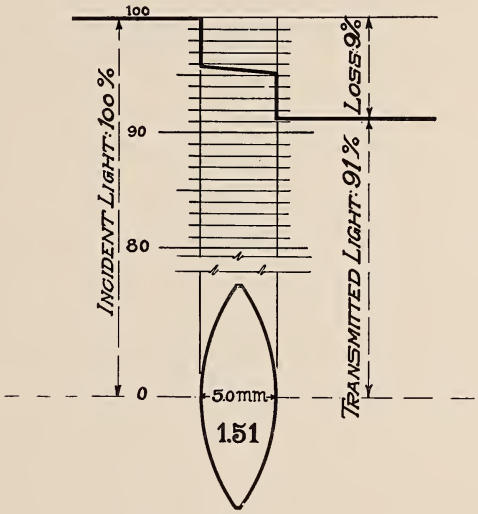


Fig. 2

shows the curves for the loss of light in a double convex lens of refractive index 1.51, at and between the surfaces.

incidence. The more nearly perpendicular the light source stands over a surface, the less light is reflected. If we now consider that the more light there is reflected at the surface, the less of it passes through the surface, it is evident that the conditions for passing the greatest amount of light become most favorable, when the refractive index is as low and the angle of incidence as small as possible. We may remember that the angle of incidence is the angle between the direction of the ray of light and the perpendicular at the point of incidence, and that therefore the angle of incidence is the smaller, the nearer the ray of light is perpendicular at the point of incidence.

The action of a lens depends on the refractive index of the material it is made of. To get any lens action at all, the refractive index has to be greater than that of air, which is 1.00. Therefore we shall always have a certain loss of light when light passes through a lens surface. The amount of this loss is determined by means of a formula which was derived by Fresnel, the famous French

mathematician and optician. He found for perpendicular incidence the following equation:

$$I - I^1 = \left(\frac{n-1}{n+1}\right)^2$$

where in I is the amount of light falling upon the surface,

I^1 the amount of light transmitted by the surface, and

n the refractive index of the medium.

The difference $I - I^1$ is the loss of light at the refracting surface.

The curve in Fig. I shows for refractive indices varying from 1.0 to 1.8 the intensities of the reflected and transmitted light.

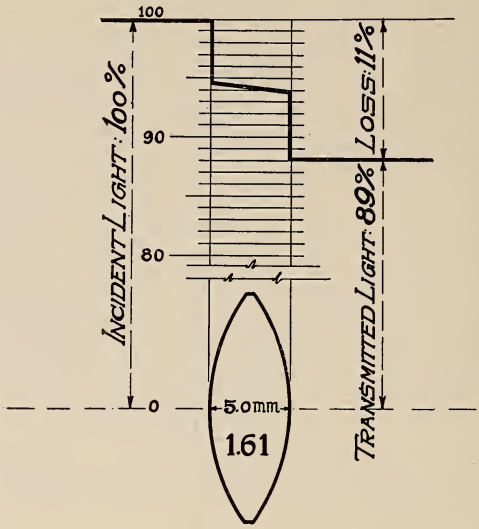


Fig. 3

shows the curves for the loss of light in a double convex lens of refractive index 1.61, at and between the surfaces.

The variation of the loss of light with the angle of incidence may be seen in the following table. It is assumed that the light in unpolarized, an assumption which satisfactorily represents practical conditions.

Angle of incidence	*Crown* 151	*Flint* 1.61
0°	Loss 4.13%	Loss 5.46%
30°	" 4.28%	" 5.64%
60°	" 9.08%	" 10.69%
70°	" 17.29%	" 18.97%
80°	" 38.92%	" 40.30%
90°	" 100.00%	" 100.00%

The refractive indices of the glasses as used in projection lenses vary from about 1.51 to 1.61.

The loss of light per surface for perpendicular incidence if for

Refractive index 1.51 amounts to 4.13%

Refractive index 1.61 amounts to 5.46%

The angle under which light rays strike the surfaces of a projection lens varies from 0° to about 30° and fortunately for the simplicity

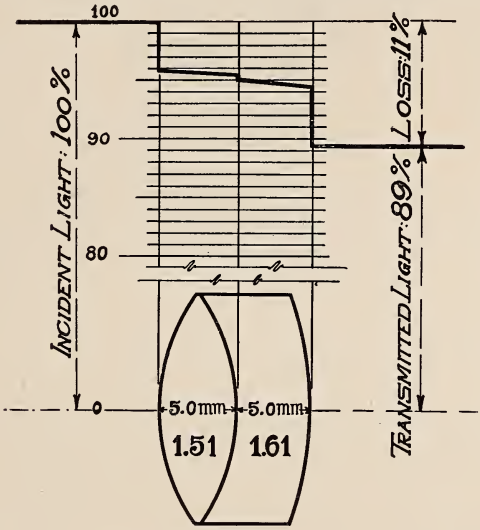


Fig. 4
shows the curve for the loss of light in a cemented doublet consisting of a lens with refractive index 1.51 and another lens with a refractive index 1.61, at and between the surfaces.

of this discussion the variation of the loss within these angles is negligible as may be seen in the table. We may therefore say that the loss of light per surface on a

Crown Glass lens.....4.2% and on a

Flint Glass lens.....5.5%

The refractive index of Canada Balsam is approximately equal to that of Crown glass and therefore if lenses of 1.51 and a Flint lens of 1.61, are cemented together, the loss by reflection at a cemented surface is very much smaller, than at surfaces bordering on air. Since the refractive index of Canada Balsam is practically the same as that of Crown glass no loss is incurred at the transition from the Crown glass into the layer of Balsam, while between the Balsam and the Flint glass the difference amounts to only 0.1 which means an almost negligible loss.

For a number of glass surfaces in air of about the same loss by reflection the total loss may be arrived at by using the compound interest formula. If the loss, p, for one surface is represented as a fraction of the initial intensity, the loss for k surfaces will be $1 - (1 - p)^k$.

The loss by *Absorption* depends on the nature of the glass and on the thickness of the lenses. Good Crown glass will not absorb more than 0.5 to 1% per centimeter thickness, while Flint glass of

1.61 refractive index, will run a little higher, from 1% to 1.5% per centimeter.

The lighter varieties of Flint glass, of indices between 1.54 and 1.61 have absorptions between these limits, while the absorption of bad glasses runs as high as 3 and 4% per centimeter.

If we take a Crown glass lens of an average of 5 mm., the losses by reflection and absorption total up as follows:

100% 95.8% 95.3% 91.3%

or about 9% per lens.

With a Flint lens of 1.61 we obtain the following data:

100% 94.5% 94.0% 88.8%

or about 11% per lens.

For a cemented lens consisting of cemented crown and flint elements we find

100% 95.8% 95.3% 95.2% 94.2% 82.2%

or again, a total of about 11%.

Figures 2, 3 and 4 represent these conditions graphically.

In this way it is very easy to form an opinion on the losses by reflection and absorption in any combination. In general it is safe for an estimate to assume the loss per single lens or per combination of cemented lenses, as they occur in projection lenses, to about 10%.

If the workmanship and material are approximately the same, and no difference exists in the geometrical arrangement, diaphragming, etc., of the lenses, the amount of light passed through is very nearly the same in all lenses that have the same number of reflecting surfaces.

A very important factor for the performance of a lens is the condition of the surfaces. Scummy and dust-covered lenses give gray pictures with no contrast, just in the same way as photo lenses will not take snappy pictures if dispersed light from finger-marks on the lens is allowed to reach the plates. It is therefore of the utmost importance that in comparative tests the lenses should be clean.

I may mention here shortly that there exists a condition of lens surfaces which is helpful in the way of reducing the amount of reflected light and increasing the amount of transmitted light. Such surfaces have an iridescent appearance which is caused by chemical action. It had been discovered accidentally in process studios that such lenses allowed shorter exposures and upon investigation, it was found that actually the amount of transmitted light had been increased. Unfortunately such action takes place for the most part on glasses which have comparatively great absorption co-efficients and are not generally used for projection lenses, and therefore, any thoughts of helping the matter by these means will probably have to be dismissed. The amount of loss by such treatment can be reduced by as much as 50%.

In conclusion I may say that all the statements made above are borne out by practical tests not only in comparatively simple combinations like projection lenses, but also in the most complicated apparatus like range finders, submarine periscopes, etc.

The High Power Arc in Motion Pictures

By Preston R. Bassett

ONE of the greatest developments in Military illumination during the war was the High Intensity Arc. In order to compete with the new methods of warfare both our Army and Navy found it necessary to demand searchlights of an intensity which had been considered unattainable. The ordinary carbon arc, such as had been used in searchlights for many years, could not be forced by any means to meet this urgent demand for more powerful searchlights. It was only the development of a new source of light which could fill this need. As was the case in many engineering branches of the service, necessity was the mother of invention, and so a new source of light was perfected and introduced into the searchlight field during those remarkable years of the war when a new development would be in common use by the Army or Navy before the public had even heard of its invention.

This new light source, which is known as the High Intensity Arc, made an advance in searchlights which was actually revolutionary since it increased the efficiency of searchlights by 500% at one step. By the end of the war, both our Army and Navy and many of our Allies were equipped with searchlights of this high power type, and the old carbon arc searchlights which were the best available only a few years ago, are now fast becoming obsolete.

High power arcs may be classified broadly as electric arcs, having positive craters with intrinsic brilliancies greater than can be obtained with pure carbon positive craters. Before explaining in detail the method of operation of a high power arc, it is necessary for us to appreciate the limitations of the pure carbon arc. Practically all of the light from a pure carbon arc emanates from the incandescent positive crater. Incandescence is a function of temperature and, therefore, in order to obtain a light source of maximum brightness, a substance must be used which can be maintained at the highest possible temperature. As is well known, carbon has the highest melting point of all substances, and for this reason it has been used in all cases where light sources of greatest brilliancy have been desired. In an electric arc between pure carbon electrodes, the surface of the tip of the positive electrode is maintained at a temperature of over 3,700 degrees Centigrade. The carbon surface, when heated to this point, gives forth about 160 candle-power for every square millimeter of its surface. This brilliancy we may call the maximum obtainable from any solid by temperature radiation. When such a carbon arc is forced by, let us say, doubling the current, the brilliancy of the crater is not increased proportionately as might be expected. Instead the carbon is consumed at a faster rate without any material increase in the temperature of the crater. It is, therefore, perfectly useless to force a carbon arc beyond a certain point

where the crater is practically at the volatilizing point of carbon and has, therefore, reached its maximum theoretical efficiency.

In searchlight work, the only practical way of increasing efficiency was to increase the intrinsic brilliancy of the source of light. Since this was impossible by using solids, an investigation was made of vapors and gases. There is no known limitation to the temperature to which vapors may be heated, but on the other hand, vapors and gases do not obey any known laws of radiation such as apply to incandescent solids. In general gases and vapors are very poor brightness producers when compared with incandescent solids. For

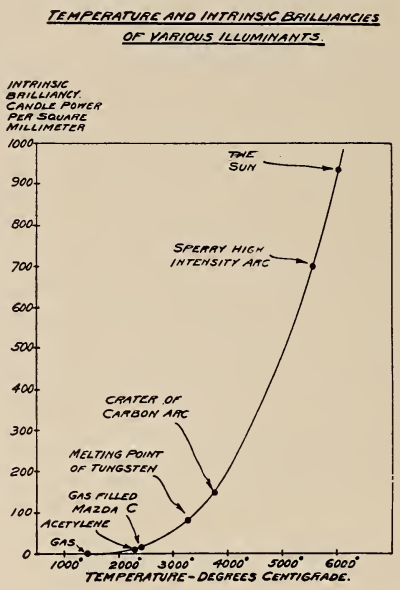


Fig. 1 — Curve showing the comparative brilliancy of common illuminants.

instance, the arc flame in a pure carbon arc consists of vapor at a temperature greater even than the temperature of the positive crater and yet, it gives a brilliancy of only about one candle power per square millimeter, as compared to the 160 c.p. per sq. mm. given by the incandescent crater. Luminescent or light-giving vapors have long been used as light sources of exceptional efficiency, but they had never even been considered as competitors with incandescent solids when intrinsic brilliancy was required. The mercury vapor arc, the yellow and white flame arcs and the magnetic arc are all among the most efficient of light sources, but their intrinsic brilliancies are very low, all of them being less than 5 c.p. per sq. mm. In the high power arc, vapor has been made use of for the first time as a light producer of excessive brilliancy. The special vapor-producing materials are placed entirely in the core of the positive

carbon. This carbon is so constructed that when burned at the proper current, it forms a deep crater. It is usually rotated to keep this crater uniform. The special flame material enters the arc entirely from the bottom of this deep crater where the impregnated core is exposed to the arc. The negative carbon is so arranged that the negative flame sweeps across the positive crater in such a manner that the light-giving vapor from the positive core is confined and compressed in the crater. By properly confining this vapor in the crater by means of the negative flame, the brilliancy of the vapor is very greatly increased, and instead of obtaining brilliancies in the neighborhood of 5 c.p. per sq. mm., we obtain brilliancies ranging

Fig. 2—The 150-Ampere High-Intensity Arc. This photograph shows clearly the excessive brilliancy of the vapor bulging out in front of the positive crater, and also the action of the forcible negative arc flame in pressing it back and confining it practically to the crater.

from 500 to 900 c.p. per sq. mm. These are figures which were hitherto unknown on earth. The sun at high noon is the only other source which man has seen that can approach such a brilliancy. The noon day sun has an intrinsic brilliancy of about 920 c.p. per sq. mm. Figure 1 shows graphically how this new type of arc compares in brilliancy with all of the brightest illuminants known. It is evident that by utilizing concentrated and compressed vapor of spe-

cial materials at temperature of the electric arc, a new form of illuminant has been introduced with many new and very interesting characteristics. It was the remarkably high intrinsic brilliancy of this new arc which gave it its value in searchlight work, but in the application of this arc to other uses other equally important properties of this light have been controlled and accentuated so that the light is also proving revolutionary in other fields.

The motion picture industry is without doubt the greatest light-using industry in the country and the demand of this industry for

Fig. 3—Photograph taken 2½ miles from a High-Intensity Arc in the Sperry 60″ Searchlight. An idea of the power and actinic value of the light may be obtained by comparing the dark lower right-hand portion of the arch which is illuminated by the street-lighting unit only fifteen feet from it.

more light has been continuous and insistent with the advance of the art. There are two main departments of lighting in the motion picture industry; the producers' lighting, which consists in lighting the studios for photographing the pictures; and the exhibitors' lighting, which consists of the light for projecting the pictures on

the screen. These two fields are very different and each has required a special development and adaptation of the high power arc.

The arc was most readily adapted to studio lighting. In this field the high intensity arc, better known as the Sunlight Arc, met with the immediate favor of producers and camera men, who found that its unique qualities opened up entirely new fields of photography. The use of a single lighting unit having an intensity of over 100,000 c.p. made it possible to invade with the motion picture camera places which were hitherto inaccessible. The largest ball rooms and theatre interiors in the country have been illuminated sufficiently to take excellent motion pictures with from two to four of these powerful units. This one use in itself is a tremendous saving in expense to the producer who is enabled for the first time to go out of the studio to any desired interior location with the same freedom that he has been used to in going out on exterior locations. This single use has made the light indispensable to producers.

In the studio sunlight arcs are of great value in illuminating the large sets. When placed at a height of about 20 feet above a set, the amount of actinic light on the set is sufficient to give good

Fig. 4—The skyline of New York taken with one High-Intensity Arc, 150 *Amperes. Both searchlight and camera were two miles from the buildings. The picture was obtained by keeping the camera open while the searchlight beam was moved over each building. The lights in the foreground are on Brooklyn Bridge.*

photographic results more than 60 feet from the unit without the use of lenses or mirrors. The open arc used in this manner as a flood-light has been found valuable in high-lighting a large set and giving a predominant direction to the main lighting, thus avoiding the disagreeable cross shadows which are so noticeable when several smaller units are used in place of one large unit.

Another use of the open flood light is the illumination of backdrops or scenery outside of windows or doors in interior sets. It is universal practice in taking artistic interiors to have windows, doors or arch-ways through which can be seen daylight or sunlight. To properly produce this effect, a great intensity of light outside of these openings is essential, since the interior is already illuminated to a

high level and the exterior must be enough brighter than the interior to give the impression of looking out into daylight. Frequently, sunlight as well as daylight, is required to enter through the opening. It is then necessary to direct the open flood light so that it falls through the opening and makes a patch of light on the wall or floor. Excellent results are obtained with the direct arc for these sunlight effects, and since the source of light, which measures only 5/8″ in diameter, is so small for its intensity that sharper shadows can be obtained with it than can be obtained with any other source in the studio.

In exterior night work the open flood is invaluable to light any large scene. In street night scenes the lights are located at positions and heights which make the scene appear as though lighted by regular street lamps. Two or three of the arcs as open flood lights will illuminate a section of a street, large enough for several hundred actors to take part in such scenes as raids, riots, etc.

Aside from the advantages of intensity and concentration of

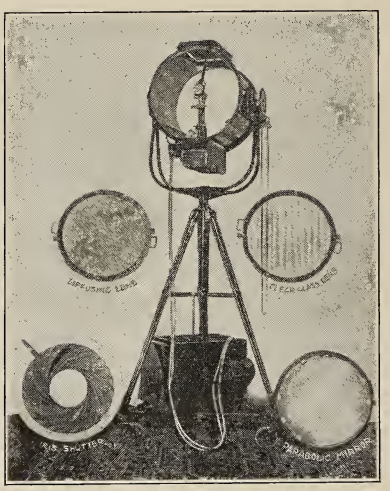


Fig. 5—The High-Power Arc Unit with its accessories. This unit consists of one High-Intensity Arc consuming 150 *Amperes.*

the high intensity arc in photographic work, several other properties of this arc are worthy of mention. In the first place the confining of the bright vapor in the intensely hot crater makes the light very steady and free from flicker. Small disturbances do not affect the light or change its intensity in the manner that is so noticeable in the small flaming arcs where the light emenates from the arc flame between the eletrodes instead of from a deep crater. Another reason for the extreme steadiness of the light is the fact that the high current used (150 Amperes) makes an arc which has considerable

inherent stability due to what might be called its own inertia. The advantages of a steady light of high candle power are universally appreciated by Motion Picture photographers.

Another feature which is partly responsible for the unusual efficiency of this unit is that nearly 80% of the total amount of light from the arc falls in the hemisphere toward which the positive carbon is facing. This useful distribution of the light is due to the fact that it is emitted from the crater, hence when the arc is viewed from some point where the crater face is not visible the candle power is extremely low. The Sunlight Arc is the first illuminant for general studio lighting which has taken advantage of this restricted distribution of light within the zone to be illuminated. Other sources of light all have a uniform light distribution in all directions, and hence must use some form of reflector in order to reflect the 50% of the light which falls away from the scene, back onto the scene. Such

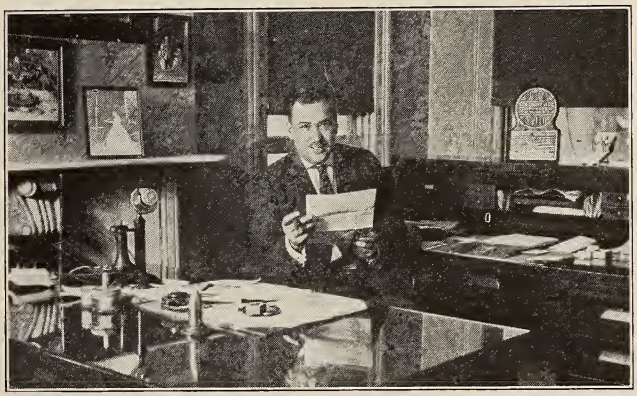


Fig. 6 (left)—A snapshot taken in an office with one High-Intensity Arc Unit with its diffusing door. Note that the light on the wall and on the papers on the desk is actually brighter than the direct daylight through the windows.

arrangements are not only inefficient, but are compromises since half of the light is direct and the other half is indirect and diffused. The high intensity arc on the other hand is capable of producing either all direct or all diffused light as desired, depending on whether the crater is pointed directly toward the scene or toward some diffusing medium or reflector.

We have spoken of the quantity of light from this arc, another and equally important aspect is the quality of the light. Photographers agree that the ideal light for photography is sunlight and north sky-light. The ideal artificial illuminant for photography is that one which most nearly approaches daylight in quality. Daylight is not highly colored, it is usually referred to as pure white, but in comparison with most artificial lights it would be called slightly bluish in hue. The high intensity arc is very similar in quality of

light to bright daylight, that is, the combination of sunlight and skylight, it is clean bluish white in color. The arc, however, although nearly identical with daylight in the visible spectrum has the advantage over daylight in the ultra-violet or actinic portion of the spectrum. The light from the sun loses from 50 to 75 per cent of

Fig. 7 (below)—Two snapshots showing the use of the direct rays from the arc passing through two small holes in a metal screen giving spot-light effects without lenses. One photograph (lower) shows full front lighting and the other back lighting.

its actinic value in penetrating through the 100 miles of the earth's atmosphere. The high intensity arc, however, loses none of its actinic value on the scene since it has no appreciable amount of atmosphere to penetrate. It has been found that for the same amount of illumination on a subject, the High Intensity Arc is more actinic than

daylight. The quality of the light has made it indispensable in the newer branches of motion picture photography. The uniform brilliancy throughout the entire spectrum gives the ideal light for motion pictures in natural colors. The actinic value of the light has made it possible to take excellent interior photographs with the ultra speed camera, taking pictures at the rate of 160 per second.

Figure 5 shows the High Intensity Arc Studio unit with the accessories which make it possible to produce either hard or soft light of almost any intensity. Some of the uses of the open arc without the accessories have been already described. The following outline of uses with the accessories will give an idea of the flexi-

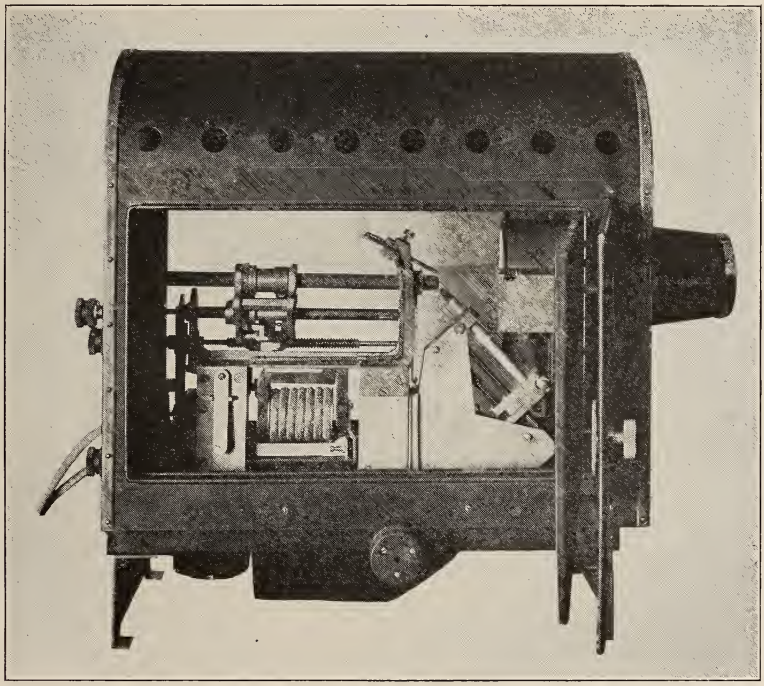


Fig. 8—The High-Power Automatic Lamp mechanism and house. Designed for 50 or 70 Amperes, direct current.

bility which can be obtained with a unit having one very concentrated and intense source of light.

When it is desired to limit the angle through which the open flood light spreads, the Iris shutter is used. By closing down the shutter the lighted area is decreased in size but the intensity remains the same. When the Iris Shutter is nearly closed the flood light then appears as a spot light since the light has a spread of only a few degrees. This is, in reality, a spot light without a lens. It can be used for special effects. This spot light also has an advantage

not obtainable in any lens spot light, that is, it can be spread from an angle of a few degrees up to an angle of over 150 degrees without decreasing the illumination. In lens spotlights the illumination decreases as the square of the increase in angle of spread.

Another arrangement of the Studio Outfit is with the diffusing front door. The purpose of this accessory is to make possible a softer light than that obtained by the direct arc.

The open arc casts very sharp edged shadows which are much desired when simulating sunlight or in special silhouette effects, but many uses demand softer shadows, especially in illuminating interior scenes. The diffusing door not only spreads the light very evenly

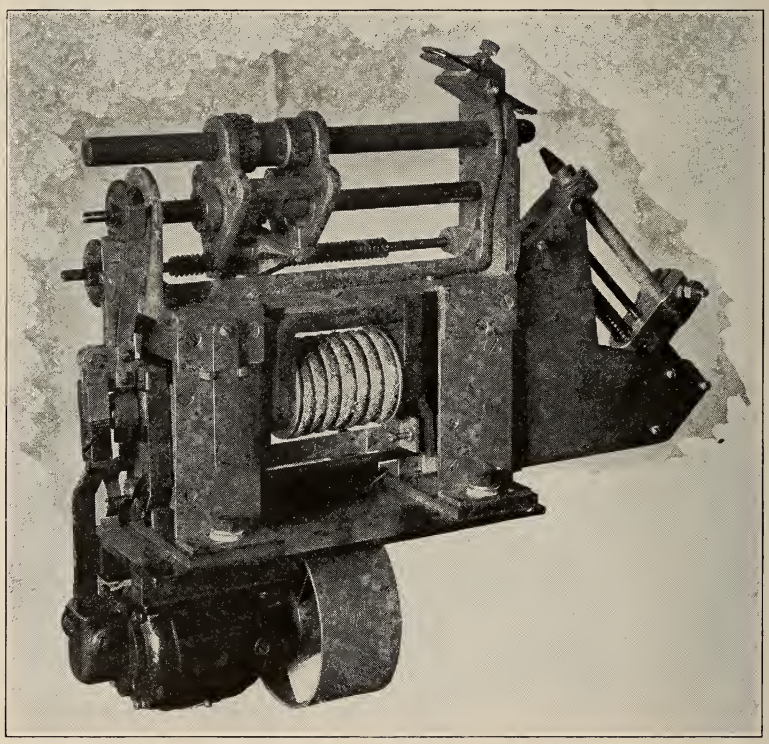


Fig. 9—High-Power Automatic Projector Lamp, showing motor and automatic features.

in all directions, but it acts as though the source of light were now two feet in diameter instead of ⅝″ diameter as it is with the open arc. Shadows cast by this arrangement are, therefore, more blended and softer.

The most usual use of this arrangement is to intensify the diffused light from a certain direction on a medium or small sized scene. It is used to best effect with other units such as banks of

mercury vapor arcs. The banks supplying the general illumination from several directions and the diffused studio arrangement intensifying this from one direction causing a more artistic effect by accentuating lights and shadows.

When the Iris Shutter is used with the diffusing door the effect is different than in the case of the open arc. Instead of changing the angle of spread, it changes the intensity of the light without affecting its distribution. Hence closing down the Iris with the diffusing door causes the light on the whole scene to fade away from full intensity to darkness. This arrangement gives the camera man a unit where he can adjust the strength of his light on the scene between wide limits and may cause the light to fade away or increase perfectly uniformly while taking pictures.

The parabolic silvered glass mirror is furnished with the studio outfit for special effect work and long range work. With the arc facing the mirror a beam is produced which measures in the millions of candle power. It is entirely too powerful to be used at short ranges except for special work. One successful short range use of this beam is in the production of an actual visible beam such as a moonbeam or sunbeam entering a window and falling across a room. It is possible to actually register the path of the beam on the motion picture film due to the reflection of light by the dust particles in the room.

The parabolic mirror is also used on large scenes when in addition to the general illumination a spot light is needed on some special part of the scene, such as the dancers in a Cabaret scene or any theatrical effect in a large set. In exterior sets this beam has been used with great success in night effects such as lightning, searchlight effects, etc. Good motion picture photography has been taken at night on exterior location with the lighting unit over one quarter of a mile from the camera and the scene.

The extreme flexibility of the high intensity arc unit with its accessories has given the directors and camera men a new tool. New applications and new effects are being produced regularly as the possibilities of this source of light with its reflectors and diffusers are becoming better understood by those who are using it.

Adapting the high power light to motion picture projection has presented many difficulties and it has only recently been satisfactorily accomplished. It must be realized that up to the present time nothing but incandescent solids have ever been used for sources of light in motion picture projection whereas in the studio lighting vapor sources, for instance, mercury vapor arc and flame arcs have been in general use since the first days of motion pictures. The high power arc for projection had to be so steady and free from flicker and all disturbances that it would give as constant and steady a light as the incandescent sources in general use. This has necessitated the development of new carbons and the design of a special mechanism for burning these carbons for projection purposes. Figure 8 shows this mechanism in its lamp house. The positive carbon is horizontal and lies in the optical axis of the condenser lenses. The negative

carbon is positioned at a steep angle to the positive carbon so as not to interfere with or cast any shadow on the optical system. Arcs with the carbons in these positions have been commonly referred to as "right angle arcs." Right angle arcs have not met with favor in the past and have not been used in any of the large motion picture houses. The causes for the failure of the right angle arc have been numerous. All previous right angle arcs have had carbon electrodes and such arcs have a strong tendency to hiss and to become uncontrollable at currents greater than 40 amperes. Moreover, such arcs have been very sensitive to charges in position of the electrodes and means of controlling the carbon feed had never been developed to a point of accuracy necessary in a right angle arc. Furthermore, if the positive carbon contains a soft core, as is general practice, this core in burning exposes a dark spot at the center of the positive crater, which in turn causes a lack of light on the center of the aperture plate and film. It is quite generally admitted that from the point of view of optical efficiency, the right angled arc is the best, since with this arrangement, the condenser lenses gather the maximum possible light flux. In the Sperry Automatic Projector Lamp all of the above mentioned defects have been overcome by entirely novel means and the gain in optical efficiency has been even greater than expected.

In this new automatic lamp a special cored carbon is used as the positive electrode. This carbon forms a deep crater which is kept filled with the luminescent vapor, several times the brightness of the surrounding shell, so, therefore, instead of having the center of the crater a comparatively dark spot, it is, on the other hand, the brightest part of the crater. In order to keep this form of arc burning in a perfectly steady manner, the positive crater has to be held within 1/32″ of the same position at all times, and the electrode is slowly rotated in this position to keep the crater burning evenly. A novel method of controlling the position of the positive crater has been developed in connection with these arcs. It is an electrical method which takes advantage of the ionized condition of the arc flame and the air immediately surrounding it. A piece of copper insulated from both positive and negative is positioned with its end just at the point over the positive electrode where it is desired to hold the crater. This copper third electrode is connected through a small magnet to one side of the main circuit. When the arc is burning, the arc flame sweeps up past the end of this third electrode. As the crater burns back to this electrode, the arc flame approaches nearer and nearer to the third electrode until the electrode is in a region of ionized air sufficient to carry enough current from the arc through the third electrode and the magnet to cause the operation of the magnet armature which in turn feeds the positive carbon. As the positive carbon is fed forward, the arc flame is also carried away from the third electrode and the current through the third electrode immediately ceases to flow. This form of control has been developed to a point of complete reliability and an accuracy of crater position better than 1/32 on an inch. The advantage of this in the projector

lamp is very evident since the crater is held positively in all three directions; up and down and laterally, it is fixed by the electrode holder which is in line with the optical axis. In the direction of the optical axis it is held accurately at one point (the desired focal point) by means of the third electrode. The negative carbon is fed by means of a coil in series with the arc. This series coil feeds the negative carbon either forward or backward by means of pawls and ratchets, maintaining a constant current at all times. This current control also automatically strikes the arc by feeding the negative carbon up into contact with the positive when the switch is closed and then drawing back until the arc length is such that the current is the desired amount. Two carbon trims have been developed and standardized, one for fifty amperes and the other for seventy amperes.

These lamps have been tried out within the last six months in many of the largest motion picture houses around New York City and the results have been not only surprising but very consistent under all conditions. One theatre having a screen 24 x 20 feet and 170′ throw, was obtaining exactly 2-foot candles on the screen by means of the regular 70 ampere carbon arc. We installed the Sperry Lamp on the same projector and obtained 6.2 foot candles on the screen or three times the screen illumination with exactly the same current. At another theatre, having a screen 21 x 17 ft. with a 200 ft. throw, we found that they were obtaining 4.1 foot candles with a 120-ampere carbon arc. Installing the high-power lamp on the same projector, 7.5 foot candles was obtained at 70 amperes. This is almost equivalent to doubling the screen illumination with a saving of 40% in current. At the Capitol Theatre, with a screen 18 x 15 ft. and a 212 foot throw a screen illumination of 5.5 foot candles was being obtained from a 125-ampere arc. The Sperry lamp on the same projector gave 8.8 foot candles at 75 amperes, which result is very consistent with the foregoing results at the other theatres.

The following table summarizes these results. The last column in this table which is headed lumens per ampere reduces all of the figures to a common basis for comparison. This figure is obtained by multiplying the foot candles on the screen by the number of square feet in the screen, giving the lumens, and dividing the total lumens by the current in amperes. The resulting figure is a direct measure of efficiency of the complete optical system, irrespective of length of throw and size of screen.

	Direct Current, Amperes	Size of Screen	Area of Screen, Square Feet	Illumination Foot Candles on Screen	Lumens on Screen	Lumens per Ampere
Carbon Arc, A.....	70	24x20	480	2.0	960	13.7
High Intensity, Arc..	70	24x20	480	6.2	2976	42.5
Carbon Arc, B.....	120	21x17	357	4.1	1464	12.2
High Intensity, Arc..	70	21x17	357	7.5	2677	38.2
Carbon Arc, C.....	125	18x15	270	5.5	1485	12.0
High Intensity, Arc..	75	18x15	270	8.8	2376	32.0

It will be readily seen that the well standardized optical arrangements as now used in all large theatres give a limiting efficiency with the carbon arc of about 12 to 14 lumens per ampere. The only method of increasing this efficiency with the standard optical system is by means of a brighter and more efficient source than the carbon arc and this has been accomplished in a striking way by means of the new high-power arc which is giving consistently about three times the lumens per ampere on the screen. With this light increase available to exhibitors, there should be many advancements and improvements in large house projection. It will be possible to use wide-angled screens in the larger sizes instead of being compelled by the lack of available light to use the narrow-angled metallized surface screens. Also it is possible by means of this new lamp to project satisfactory pictures on screens larger than has heretofore been practical. This may increase the size and depth of the future large motion picture houses, if an increased seating capacity is still desired. It will certainly make the outdoor moving picture in amusement and public parks much more popular, since in this field the smallness of the screen and the lack of sufficient illumination has been the greatest drawback.

But the most urgent need for more light on the screen at the present time is caused mainly by the increasing density of the films which are now being released by all of the largest producers. In addition to the extreme density of the artistic feature films now being produced, more than half of these films are also toned or tinted. This reduces the screen illumination still further by an amount varying from 40 to 90 per cent. Projection equipments which could project very satisfactorily the motion picture play of four years ago, cannot give the same satisfaction with recent films without at least doubling the available light. The high power arc arriving as it has at just about the same time as the dense artistic tinted feature film will solve the problem of maintaining satisfactory projection in the large houses by more than doubling the available light and also by rendering the color tinted films in brilliant true colors, due to the pure white quality of the high power arc.

Design of Power Plant and Electrical Distribution in Large Studios

By Jac. R. Manheimer

NOTE—The following paper covers a description of the power plant and electrical distribution equipments designed and installed in the new Eastern Studios and Laboratories of the Famous Players-Lasky Corporation in Long Island City, N. Y., and the Studios and Laboratories of the Fox Film Corporation in New York City.

SYNOPSIS

By Jac. R. Manheimer

Introduction.

FAMOUS PLAYERS-LASKY CORPORATION STUDIO AND LABORATORY

I. General description of buildings.

II. Power Plant.
- a. Description of high-tension central station incoming service lines.
- b. Description of 7,600-volt motor generator installation.
- c. High and low tension switchboard control.
- d. Transformer equipment for general lighting and power.
- e. Notes on the flexibility of design and provision for expansion.

III. High-capacity feeder system for studio equipment.
- a. Description of bare bus bar feeders.
- b. Advantages of this type of construction as compared to cable and conduit systems.

IV. Studio switchboards, remote control system and plugging box equipment.
- a. Description of automatic remote control switchboards.
- b. Advantages of remote control system over old systems.
- c. Description of overhead structural arrangement.
- d. Description of new monitor control station for remote control system.
- e. Disadvantages and criticisms of overhead system.

V. Telephone systems.

VI. Fire alarm and watchman's systems.

VII. Special signalling systems.

VIII. Laboratory.
- a. Electric service supply.
- b. Motor generator equipment for lamps on printing machines.
- c. Description of equipment on cartoon cameras.
- d. Miscellaneous features.

FOX FILM CORPORATION STUDIO AND LABORATORY

I. General description of building.

II. Source of current supply.

III. Feeder system for studio switchboards.

IV. Studio switchboards, remote control and plugging box equipment.
- a. Application of remote control to switchboards.
- b. Arrangement of wall and overhead plugging equipment.
- c. Description of overhead steel track system.
- d. Description of remote control stations.

V. Advantages and disadvantages of combination overhead and floor systems.
- a. Comparisons with other systems.
- b. Description of work-light circuits.
- c. Description of watchman's lighting circuits.

VI. Telephone systems.

VII. Fire alarm and watchman's systems.

VIII. Laboratory.

In modern studio design, the greatest problem before any studio engineer or architect is undoubtedly that of adequate and proper facilities for lighting the various stages. The arrangement of stages and the locations of lights is generally known to be the most uncertain feature in the operation of a studio. This condition requires the utmost flexibility. In the control of the studio lighting in large projects such as the Famous Players-Lasky and Fox Film Studios, the arrangement of the electrical equipment is a matter of prime consideration.

In the early days of the motion picture studio, the lighting equipment was arranged in a manner similar to that of the legitimate theatre stage and very little thought was given to the entirely different character of the work executed in the studio. In the beginning this make-shift was not so noticeable, due principally to the fact that the industry was "feeling its way" and had not yet started to broaden out into an established industry requiring intensive production. Studios of more than one or two stages were unknown and probably unthought of. Instead of a number of different pictures or scenes being filmed at the same time in the same building, usually one complete picture or serial was finished before another one was begun. There was employed during this time only one director. The studio itself was still in an experimental and development stage, as were other branches of the industry.

In studios where sunlight was not used, cables were strewn haphazardly across the floors and hung or festooned across the structure of the building from a central switchboard to the various stages for supplying the floor and overhead lamps. The lamps were controlled by men stationed both at the lamps and at the switchboard. The men operating this equipment received signals and instructions, from the director or camera man, which were supposed to be executed properly, promptly and in synchronism. As happened quite frequently the misunderstanding of the signal by a single man meant a retake of the entire scene, loss of time for players, directors and stage hands. Strange to say, many of these conditions have carried over to a fairly recent period, and it is only within the last two years that any great strides have been made in the efficient and proper electrical distribution and control of artificial lighting for studios.

The method of arranging the lights to be controlled by the director or camera man promptly, efficiently and without errors, was one of the first questions to be considered.

A problem which presented itself in the two mammoth studios to be described in this paper, was the design of a suitable equipment which could be used by from eight to eleven directors simultaneously working on adjacent stages, without interference with each other.

This paper describes only generally the various considerations and engineering problems which went into the design of many of the special features in these projects and is not intended to present the electrical engineering of the problem with its many technical calculations and computations leading up to the results obtained. The

paper is illustrated with photographs taken during the progress of construction and upon completion of some of the work.

FAMOUS PLAYERS-LASKY STUDIO AND LABORATORY

I. General Description of Buildings.

The Famous Players-Lasky Studio building is located at Pierce Street, 6th and 7th Avenues, Long Island City, and is a reinforced concrete structure containing upper and lower studios each measuring approximately 230 feet in length by 120 feet in width. The clear height of the upper studio is approximately 40 feet and of the lower studio approximately 20 feet. Around the studio section of the building the various offices, carpenter shops, prop rooms, scene

Figure 1—Studio and Laboratory Buildings, Famous-Players-Lasky Corporation, Long Island City.

docks, etc., are located. Located on the second floor in the rear half of the building are the men's and women's dressing rooms, all of which are provided with daylight in addition to artificial light. In order to provide daylight for some of the inside dressing rooms, an ingenuous saw-tooth roof construction was employed, as is illustrated in Figure No. 1.

The main studio is covered over by a series of iron grating footwalks which are approximately on the same level as the roof of the dressing room and executive sections of the building. The arched

truss part of the roof provides working space over the main studio, space for monorail system carrying the overhead lamps, overhead switchboard equipment, etc., as will be subsequently described. The two-story building shown to the left is the Laboratory Building owned and operated by the Famous Players-Lasky Corporation, also of reinforced concrete fireproof construction.

II. Power Plant.

The Famous Players-Lasky Studio is supplied with 7,600 volts, 60-cycle, alternating current, by the local lighting company. The Famous Players-Lasky Corporation has a wholesale contract with the Lighting Company for high-tension current, based on an average maximum demand for a 30 minute period during peak load and it is hoped that the cost of current will be brought down to approximately 2 cents per K.W. hour when the studio is in full operation. The

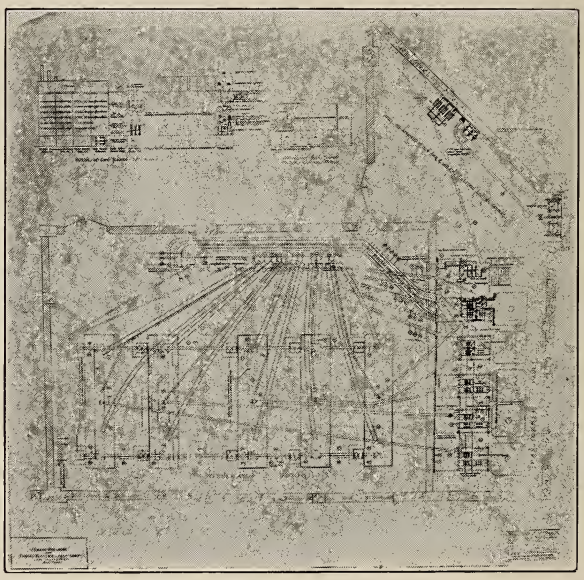


Figure 2—Detail plan of Generator Room and Transformer Vault.

7,600-volt lines are brought into the building underground to the lower level of a high-tension vault, as shown in Figure No. 2, through the Lighting Company's primary switches, recording watthour meters and demand meters and from there run to the consumer's main-line oil switch and sub-oil switches and transformers. The transformer equipment is used for general house lighting and power. The 7,600-volt high-tension service is run through the various disconnect and oil switches directly to 435 H.P. synchronous motors, each direct connected to two 150 K.W. generators.

Each one of these units of which there are three at the present time, has a direct current capacity of 300 K.W. and designed to

supply 3-wire system at 250/125 volts. The motor generators installed are of the three-unit type arranged with two generators mounted on a common shaft on either end of the driving motor. This type of apparatus has been found most suitable for supplying direct current in studios. It is generally known that the three-wire system of distribution is the most economical, but that the possibilities of unbalancing such a system in a studio are very great. With the standard type 3-wire generators as are ordinarily furnished for commercial work, the percentage of unbalancing of load on either side of the three-wire system is rarely if ever permitted to be more than 25%, which is the maximum capacity of the special balancing coils, balancer set or compensating taps inside of the machine. However, in studios, the nature of the load is such that the percentage of unbalancing is very high and sometimes reaches as much as 100%. There is no commercial type three-wire generator made which will operate under these conditions and the universal practice, therefore, now seems to lean towards the application of three-unit sets where the two generators on the same set are connected in series to obtain the Edison 3 to 2 wire system in identically the same manner as was employed by the large central stations in the early days of the Edison three-wire system. The neutral or middle leg of this system is connected to the tie between the positive lead of the one machine and the negative lead of the other.

A very interesting paper* was contributed by one of our members describing the various advantages obtained by the use of this type of apparatus.

A feature of this installation, which is rather unusual, is the application of the 7,600 volts direct to the synchronous motors without interposing "step-down" transformers.

With this arrangement transformer core losses and transformer difficulties are eliminated as well as the loss of valuable space, bulky and expensive oil switch equipment and the original investment of transformers with maintenance, depreciation and interest items charged against them.

So far as safety of operation of the high-tension motors is concerned, ample protective devices are provided, guarding against accidental or intentional contact with the live parts of the high-tension equipment. The connection to each and every piece of high-tension apparatus is intercepted by a double throw disconnect switch with lower jaw grounded. When it is necessary to perform work or make repairs on any part of the equipment, the high-tension disconnect switches on this circuit are thrown into the lower jaws. This opens the supply circuit and connects the equipment to the ground, thereby insuring the repair man or operator that the apparatus upon which he is to work is of the same potential as the ground and also at the same time dissipating all static or condenser charges.

The arrangement of supplying the various 7,600-volt motors on

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*Campe, H. A. Transactions, October, 1919.

the motor generator sets is shown diagramatically in the plan view of Figure No. 2, and it will be noted that the only high-tension connections coming into the generator room are those running directly into the generator pits under the 435-H.P. motors. These connections are all thoroughly insulated and protected so that workmen in the generator pits cannot make accidental contact with any of the high-tension connections. In addition to this safety feature, a complete network of grounding conductors has been run under the floor of the transformer vault and generator room, consisting of No. 4/0 cables laid in the concrete with taps and connections to ground shafts

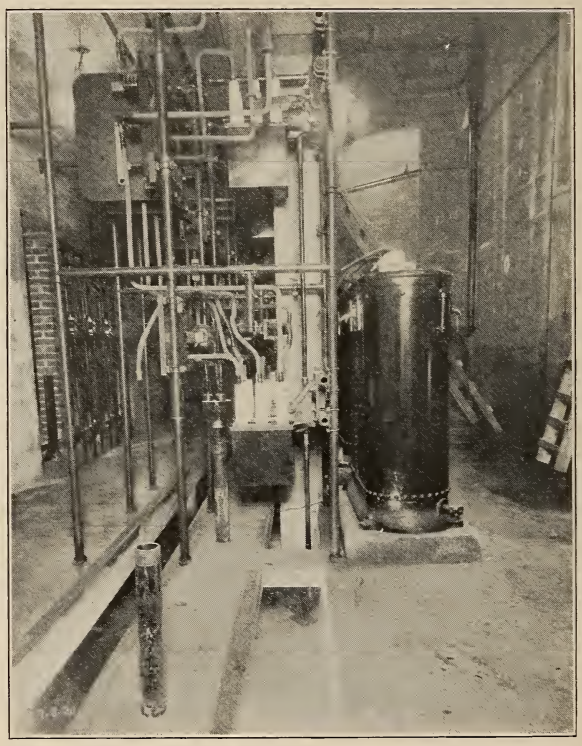


Figure 3—Lower level of high tension vault during construction.

sunk 18 feet to permanent moisture. These grounding shafts have been spotted around the equipment on about 10-foot centers, so that the failure of any one ground will not interfere with the effectiveness of the rest of the grounding system.

The plan in Figure No. 2 shows five auto transformers used for starting the 435-H.P. motors on the five motor generator sets. The present equipment consists of only three units, but all underground conduits and foundations have been prepared for two additional sets.

Figure No. 3 is a photograph of the lower level of the high-tension vault during construction, showing on the right the auto

transformers for starting the high-tension motors and the oil switches and high-tension disconnect switches mounted on pipe frame construction. The special double floor construction designed to receive the various oil switch operating mechanisms, thereby leaving the floor of the transformer vault free and clear of all obstructions and projections to trip over, is shown in the illustration. Figure No. 3 shows the openings in the floor without the trench plates in place. To the left of the photograph can be seen the rear of the high-tension control board which is mounted into the wall separating the transformer vault from the generator room. The various oil switch operating rods are seen dropping to the lower level of the double floor and rising at the oil switches. The high-tension service is tapped off and feeds through all the equipment shown in Figure No. 3, directly to the motors.

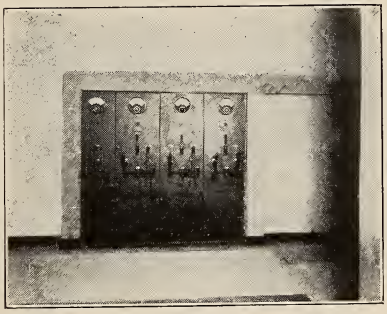


Figure 4—7,600 Volt dead front flush type control board.

A noteworthy feature of this installation is the arrangement of the wires from the various instrument transformers which are run inside of the pipe racking over to and connecting with the high-tension control board.

Figure No. 4 is a front view of the high-tension control board mounted flush into the wall separating the generator room from the transformer vault. This switchboard is entirely dead front and provisions have been made in the wall for the two future panels to control the additional motor generator units. The first panel at the left controls the main high-tension oil switch for the entire plant. Panels 1, 2 and 3 are used to start the 435 H.P., 7,600-volt synchronous motors driving the motor generator sets. A branch of the high-tension service rises to the upper level of the transformer vault shown in Figure No. 5 and is tapped off to the various high-tension disconnect switches and fuses protecting the transformers whose secondaries supply 220-110 volts, three-phase current for the general house lighting and power.

Figure No. 5 shows the work under construction and gives an idea of the relative arrangement of upper and lower levels of transformer vault and also shows in detail the rear of the main high-tension control switchboard.

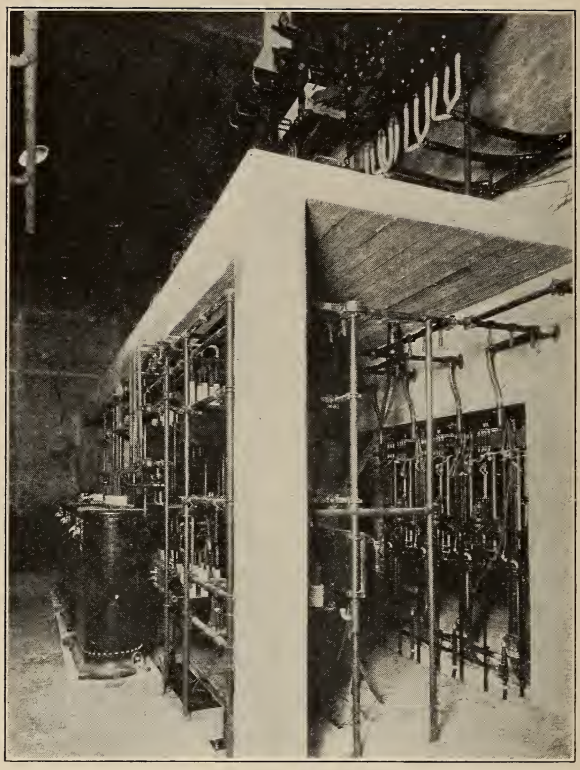


Figure 5—Perspective of upper and lower levels of high tension vaults during construction.

Figure No. 6 shows the arrangement of the lighting and power transformers on the upper level and it is to be noted that each trans-

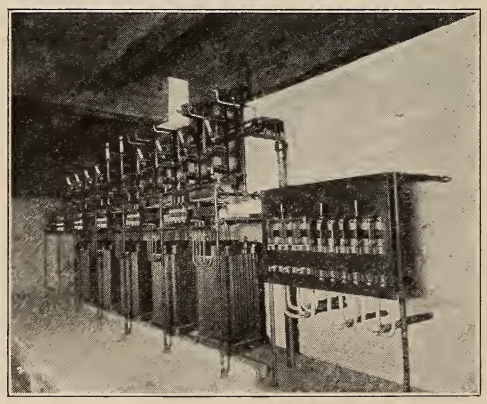


Figure 6—Transformer equipment for house lighting and power, upper level of high tension vault.

former is provided with not only primary disconnect switches which are connected to the high-tension bus bars but also with secondary disconnect switches which in turn are connected to the main low-tension bus bars running horizontally over and across the various transformers to the main low-tension service board shown to the right of the photograph. From this service board, the feeders run to the main low-tension switchboard in the generator room. The pipe racking and disconnect switches shown in this photograph were designed so that when a repair or replacement of any transformer is required, it is necessary for the operator merely to open the secondary disconnect switch and throw the primary disconnect switches into the lower jaws, thereby insuring the repair man that the transformer leads are of the same potential as the ground. The racking and secondary bus bar feeders are arranged so that a transformer can be removed by loosening a few of the connections and

Figure 7—General view of generator room, showing main switchboard at left.

rolling the transformer out of its compartment without interfering with the operation or the arrangement of the rest of the equipment.

From the main low-tension service board shown in figure No. 6, light and power feeders are run to the main low-tension switchboard in the generator room shown in Figure No. 7. This switchboard is approximately 35 feet long and 8 feet high and is designed to control ultimately 10-150 K.W., 125-volt direct current generators operated in pairs. The direct current generator control panels are located at the right of the switchboard and three panels are equipped at the

present time for the control of the present three sets of generators. Blank panels have been provided for mounting future generator equipment. The studio circuit breaker sections are located in the center panels of the switchboard and are each equipped with 5,000-ampere, two-pole circuit breakers and 5,000-ampere, three-pole, knife switches with ample space for recording instruments. The left sections of the switchboard are used for feeder switches controlling the various house lighting and power feeders. All the various generator leads are brought to the main switchboard with the exception of the equalizer leads which connect to knife switch pedestals, two of which are installed with each motor generator set. The various outgoing feeders and the generator leads are all brought underground into the switchboard through a long trench. The usual method of dropping conduits down to the top of the switchboard from overhead is avoided. The generator sections of the switchboard, Fig. 7, are each equipped with safety stop devices and the circuit breakers are interlocked with the main oil switches, preventing the operator from throwing the generators on to the direct current bus bars unless the high-tension motor driving the generators is running. The motor generators are equipped with over speed devices which will trip out the main oil switches should the machines get out of step.

The generators are of standard General Electric 40° design, but the motors driving them were specially designed for the present 7,600-volt service with special taps for a change-over to 4,000-volt service which is contemplated in the near future.

The motors are of the synchronous type, rated at 435 H.P. and will operate with 25% overload for a period of two hours with very little rise in temperature. A feature which cannot be emphasized too strongly is that of intermittent overload capacity in equipment used in large studios. The compensators used for starting these synchronous motors also have a special "five minute" rating for starting duty which provides additional insurance against burning them out or over-heating under abnormal starting conditions. This feature is also important since these sets may at some time be started by an inexperienced operator and may require several attempts to start a machine and bring it up to synchronous speed so that it can be thrown on the line without causing a surge disturbance.

III. High Capacity Feeder System for Direct Current Studio Equipment.

On account of the large current requirements for the studio lighting equipment, a great deal of consideration was given the feeder system intended to supply the various studio switchboards. It was considered quite impracticable to install the feeders using the conventional insulated cables in conduits, since the cables required would have been of unusually large sizes and the conduits to protect them correspondingly large and cumbersome. The feeders to the various switchboards could have been run by doubling or trebling the number of cables per leg and with this arrangement, each switch-

board would have been provided with a separate feeder and the total load taken off any single switchboard would have been limited to the size of the individual feeder supplying it.

To avoid these conditions and to provide a feeder system of the utmost flexibility and one in which its capacity might be increased at some future time without extensive changes, a bare bus bar system was designed having sufficient capacity to take care of all the present requirements. This consists of a single bus bar feeder for each studio which passes virtually through all the switchboards. If necessary the entire plant capacity can be taken off a single switchboard without overloading the feeder. In addition to this feature, a minimum drop in voltage is obtained and the studio is utilizing 100% of the copper installed in the building all the time. With a separate feeder system (individual feeder to each switchboard), there may be times when as much as 90% of the copper is not in use. The bus bar feeder system is nothing more or less than an extension of the main switchboard in the generator room and as designed in this studio is equivalent to the power plant being placed up over the studio alongside of the various studio switchboards. There are many advantages accruing from a system of this kind, some of which may be briefly stated as follows:

a. The currents handled are relatively large compared to those that can be handled by insulated cables on account of the greater amount of radiating surface exposed to the air and the facility for keeping the copper at a lower temperature for much greater current densities.

b. Due to the low operating temperature of the bus bars as compared to cables, the actual power loss in the copper is less.

c. Due to the large amount of radiating surface, the overload capacity of a bus bar feeder is greater than that of any cable having an equivalent copper cross section.

d. Due to the absence of deterioration of insulation (porcelain is used for insulation), a bus bar installation is practically permanent. The life of a cable installation may be from five to ten years, depending upon the overload demands made on the system and is dependent entirely upon the detorioration of the cable insulation.

e. Bus bar systems offer easy facilities for increasing the capacity by simply adding laminations. Cable systems require the installation of new conduits if the present conduits are too small or else the withdrawal of present wires and the installation of heavier wires. Bus bar systems offer the advantage that they may be increased in capacity in one section of a plant with copper removed from other sections of the plant which may not be so heavily loaded. It is quite impossible to do this with cables.

f. Bus bar systems are easy to inspect and offer splendid facilities for making repairs. Cable system when needing repair, usually requires an entire new length of cable should even a small section of it become damaged.

g. So far as the actual insulation is concerned, bus bars are

better insulated than the ordinary interior rubber-covered cable for the reason that high-voltage porcelain is used throughout (in this particular installation the porcelain was tested at 6,600 volts whereas the actual operating voltage is 110), and the insulation resistance of a bus bar system as shown by actual test is many times greater than that of an insulated cable system using commercial grade of insulation. The bus bars in this particular installation are protected by wire grille mesh work with large air spaces between the grille work and copper work so that it is practically impossible even if the grille work is damaged to come in contact with the bus bars.

h. The cost of a high capacity bus bar system for large amounts of current usually, as in this case, is not much greater than that of a cable and conduit system having the same capacity, and affords all the additional advantages mentioned.

The outstanding feature of the design of this system is the fact that the institution can expand and the feeder system can also expand without any material changes to the present system and with very little additional cost. The feeder system installed in the upper studio is intended for an intermittent load of 10,000 amperes at 125 volts or 8,000 amperes continuously and in the lower studio an intermittent load of 8,000 amperes at 125 volts or 6,000 amperes continuously.

Figure No. 8 is a photograph of the bus bar feeder (before being enclosed with grille work) coming out of the generator room and rising up the studio wall. The insulated heel supports shown are designed to take the vertical thrust of the bus bar and to withstand the dead load as well as the strains due to expansion and contraction of the copper.

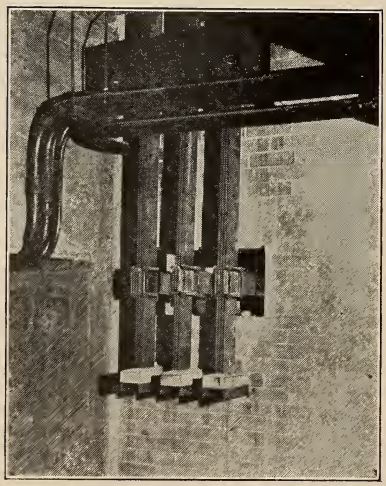


Figure 8—Bus bars coming from generator room and rising to footwalks.

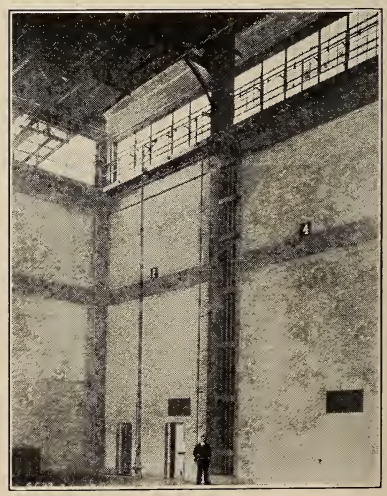


Figure 9—View showing entire vertical bus bar running up wall of upper studio.

The insulators used for supporting these bus bars are designed to each carry an ultimate stack of six 4″x ¼″ copper bars and the braces are installed approximately every six feet.

A characteristic of a bus bar system which must be taken into consideration is the phenomena of mechanical forces due to magnetic effects tending to thrust the bus bars apart under short circuit conditions. It was calculated that the horizontal thrust strain on short circuit for this particular system is approximately 409 pounds per foot with 8″ centers between opposite polarities. The wrought iron braces and insulators being placed every six feet, required insulators designed to withstand a short circuiting stress of 2,454 pounds per insulator. The insulators furnished for this installation were tested at 4,100 pounds cantilever stress. Another condition which had to be provided for, was that of expansion and contraction of the copper with varying temperatures based on the worst condition in the winter when the building might not be heated, to the highest temperature in the summertime. In order to provide for the expansion and contraction, the bus bars are so held in the insulators that they may slide through them without subjecting the porcelain of the insulators to any abnormal strains. The insulator bases are provided with slotted holes for expansion and it is intended that these also will assist in compensating for the expansion and contraction. Ordinarily in a system of this kind, special extra flexible "U"-shaped laminated expansion joints should be installed along the line of the bus bar which function very much the same as expansion bends do on a steam line. However, on account of the peculiar conditions in this studio, the system is arranged without these bends.

Another feature in the design of the bus bar system was the question as to whether the bus bars which come in lengths of from 10 to 12 feet should be butted or lapped between lengths and it was decided that all vertical runs should be butted so as to prevent a bar from falling out of the insulator and sliding past a lower bar in the event of any undue expansion. Where the joints were butted, copper splicing plates were used on each side of each lamination to carry current from one length of bus bar into the other. These splicing plates and bus bars are all "ground in" and clamped together solidly to obtain minimum surface contact resistance. In the horizontal bus bar runs, the ends of the various lengths of bar were also "ground in," but lapped instead of butted and clamped together solidly to obtain minimum contact resistance. In this type of construction, the copper splicing plates were unnecessary.

Figure No. 9 is a photograph of the bus bar system for feeding the upper studio run up the surface of the upper studio wall to the roof space above.

Figure No. 10 is a photograph of the feeder after the switchboards had been set in place and after the bus bars had been enclosed with wire grille. This bus bar feeder passes through five switchboards similar to the one which is in the foreground of the photograph and there are five other similar switchboards in the roof space

over the upper studio, which are sub-fed from those just mentioned.

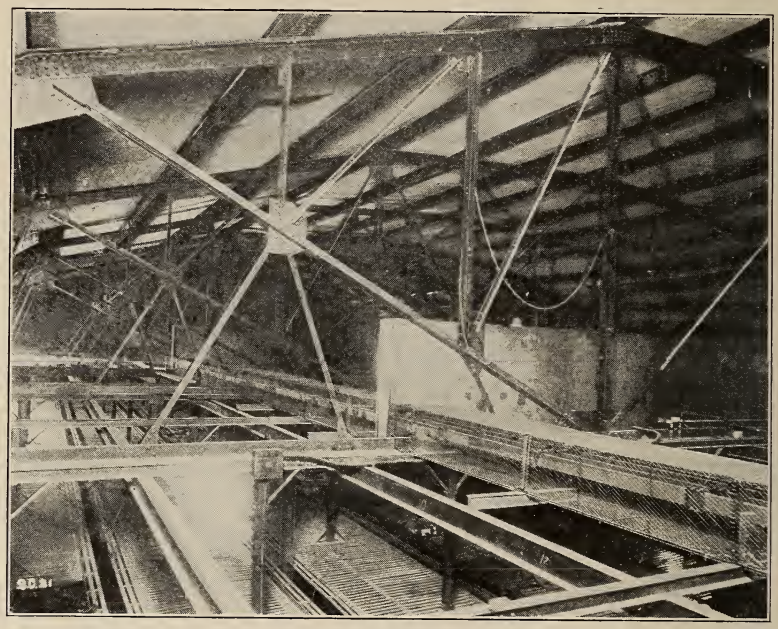


Figure 10—Main bus bar feeder running thorugh roof space and overhead switchboards after completion.

IV. Studio Switchboards and Plugging Box Equipment.

Over the upper studio are ten remote control studio switchboards installed similar to the one shown in Figure No. 11. In the lower studio there will ultimately be approximately nine of these. This photograph shows the switchboard mounted in a steel cabinet braced to a roof truss and consisting of the remote control section used for controlling the floor, lamps and top lights from a control box placed on the studio floor and a distribution section which supplies the various high capacity pockets for use with spotlights and high intensity arcs. The spotlights and arcs are usually hand-controlled at the lamp and it has, therefore, been considered inadvisable to put these on the remote control section. The advantages of the remote control system designed for this studio over that of the old type conventional switchboard systems, are many.

a. By its use, valuable floor space is not occupied by cumbersome switchboards.

b. By installing the switchboards overhead, the various stage cables may be dropped from overhead to the exact point at which they are required on the studio floor instead of having them lie across the floor interfering with stages in operation and with the moving about of scenery, floor lamps, etc. This interference is not only annoying but actually ruins the insulation on the cables.

c. The switchboards being placed out of the way, it is impossible for anybody to touch the live parts or to be near any arcs of the switches when making and breaking circuits.

d. By its use, several stages may be worked at one time in the same studio without confusion, since the director need not shout to the operator at the switchboard controlling his stage, thereby disturbing his own and the other companies which may be working, or cause delays due to misunderstandings on the part of the switchboard operator.

e. The facility for the director or camera man to operate or directly supervise at close range the lighting on his own stage without calling for an electrician and without disturbing or distracting the players' attention by shouting orders to other people.

f. The switchboard operator need not remain at the switchboard

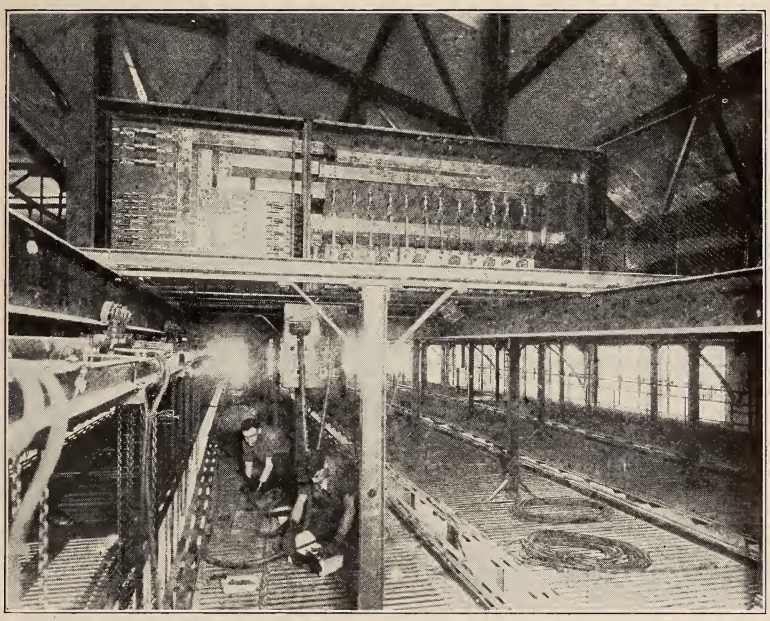


Figure 11—View showing 6-gang plugging box and method of plugging in on footwalks over studio.

waiting for a cue to switch "on" and "off" lights. Almost any kind of special effect lighting can be controlled from the stage in combinations of one, two, three or four groups. It is also possible to arrange a switch on the "props" itself which the actor can operate so as to obtain absolute synchronism of the lights with the action of the play, eliminating thereby the time interval or lag usually noticed on the screen when the actor is supposed to turn "on" or "off" the lights in the room which he is entering or leaving.

g. To obtain lightning effects with the old type of switchboard, it was necessary for the switchboard operator to pull open

and close one of the large master knife switches which not only caused considerable arcing of the switch and distracted the actor's attention, but also burned away the switch parts so that replacements or repairs were often necessary after such a scene.

With the remote control system, the director or camera man has at his command a number of keys which control the various lights or groups of lights as desired. With these operating keys, it is possible to obtain effects identical to those produced on the theatrical stage. The lights can be instantly turned off as soon as the scene is completed or while the scene is held for further instructions or rehearsal, thereby effecting a considerable saving in current consumption and the trimming of arc lamps.

Each of the remote control switchboards in both upper and lower studios are equipped with six sets of Lasky type contactors manufactured by the Sundh Electric Company. These contactors

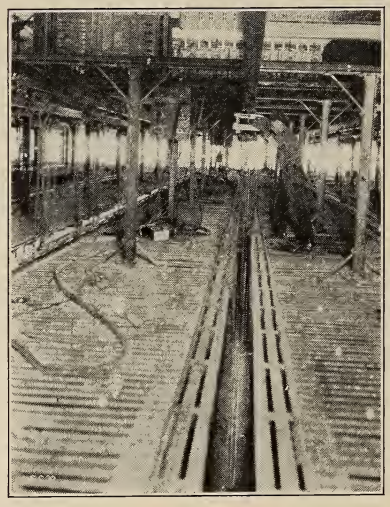


Figure 12 — Method showing manner of shifting top lights on overhead monorails. Also note surplus cable not required on studio floor.

were designed to withstand a continuous overload of 100% and are provided with special magnetic blowouts so as to extinguish heavy inductive arcs on breaking the circuit.

Referring to Figure No. 11, the bus bar feeder is shown passing through the lower right-hand portion of the switchboard and the switchboard bus bars tapped directly into this feeder. The fuses shown over the contactors protect the various contactor circuits and when repairs or replacements are necessary on any single contactor, its fuses may be removed without interfering with the rest of the equipment on that particular switchboard. From the knife switch section of the switchboard, branch feeders are run to the various spotlight and arc pockets located over the footwalks of the upper

studio. From each group of switchboard contactors in upper studio feeders are run to a plugging box placed directly underneath the switchboards as shown in Figure No. 11. Each plugging box has a capacity for six three-wire circuits arranged for connecting to six-gang portable spider boxes placed on the footwalk for the top lights or on the studio floor below for the floor lamps, and each contactor unit thereby controls all the lights connected to a six-gang spider box.

The overhead footwalks as shown in Figure No. 12 also hold the surplus stage cable and are used for facilitating the moving about of the overhead lighting equipment. A system of monorails supporting the overhead lamp equipment runs lengthwise through the entire studio on approximately seven-foot centers. These monorails hold rolling carriages and chain blocks dropping through 6″ slots in the

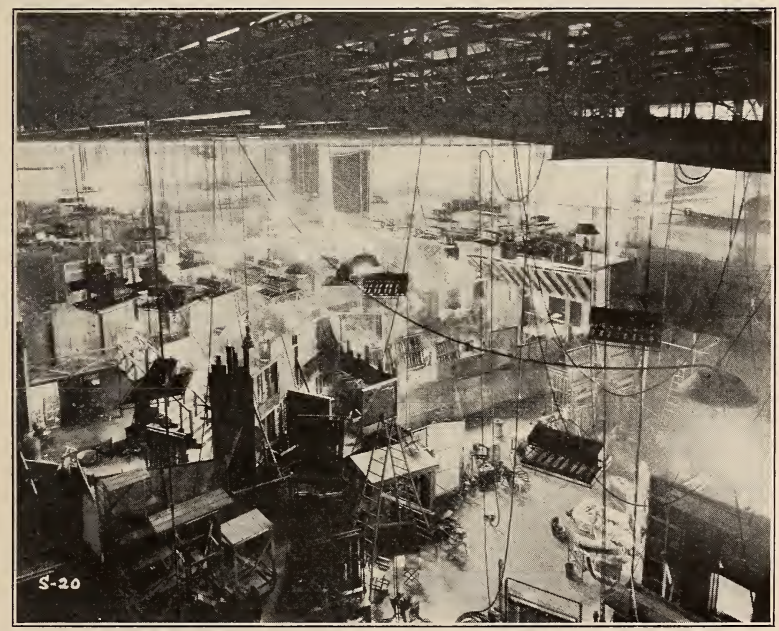


Figure 13—View of part of upper studio in operation.

footwalks from which the Cooper-Hewitt and other overhead lights are hung. This photograph shows one of the men pushing the rolling carriage along the monorail.

Figure No. 13 is a photograph of part of the upper studio showing stages set up with top lights, etc. The scene docks are shown to the right. In the foreground of this photograph is a cable dropping down from overhead to a portable Monitor station on the floor which is used by the camera man or director. The photograph does not show any stage set up at this particular point, but these cables may be dropped to any part of the floor as desired.

The Monitor studio remote control station as shown in Figure No. 14, specially developed for the Famous Players-Lasky Corporation, consists of a series of "break-back" switches which are thrown from one side to the other or held in a neutral center position similar to the listening keys on a telephone switchboard. These stations are ruggedly made and designed to stand all the abuse which equipment of this kind is subjected to in a studio. The pin plug connector coupling at the top permits removing the station from the portable cable so that it is unnecessary to hoist the heavy box out of the way. The left vertical key of this device is a Master which controls the left positions of all of four of the sectional keys. The left positions of the remaining two sectional keys are connected directly to the line and are not controlled by the Master. The upper right vertical key is also a master which controls the right positions of all of the sectional keys. By means of the Master keys, two

Figure 14—Photograph Showing Portability of Monitor Remote Control Station

large groups of lamps can be controlled in one operation and by means of the lower left positions of the two lower keys, a third group of lamps can be controlled independent of the Masters. One of the section keys can throw "on" or "off" all the lamps connected to a single spider box usually consisting of six. The operation of one Master can throw "on" or "off" all the lamps connected to six spider boxes usually consisting of about 36 lamps. As previously stated in the design of the contactors, 100% overload capacity was provided for, and the contactors were designed not only to

carry this overload without perceptible heating but also to break the circuit without dangerous arcing or deterioration of the contact surfaces. The Monitor remote control stations are also arranged with auxiliary pin plugs in the lower part, not shown in the photograph, whereby the master keys on the control station can control all the lamps corresponding to two or more other control stations with a single operation. This feature is accomplished by connecting together the various control stations by means of light portable No. 14 gauge conductors in train line fashion and this arrangement will permit the various switchboards to function in a manner similar to the Master Controller on an electric railway train consisting of several cars. The principles of the remote control system are by no means new. For the past ten years because of the safety, simplicity, saving in time, minimizing of maintenance expense and the absence of delays due to breakdowns, it has been developed and applied to the largest industrial plants in the world where hundreds and hundreds of horsepower in motors are remotely controlled.

For the lower studio, the same type of station is being constructed with the exception that there will be three Master keys instead of two, the left positions on all of the sectional keys being controlled by two Masters instead of one.

Figure No. 14 gives an idea of the compactness and portability of this control station and one must marvel that this little box functions as completely if not more so than the old-time conventional switchboard that usually occupied from 40 to 60 square feet of valuable studio floor space.

Disadvantages.

The various advantages of the overhead system as installed in this studio are many but there are a few disadvantages of which mention might be made at this time.

a. For studios having considerable height, such as this one, the cables dropping down from the footwalks are very heavy and difficult to handle unless a winding reel or special counterweight system is employed. The result is that the cables are not always lifted up and dropped to the most advantageous locations, but are partly laid on the floor.

b. Another disadvantage is the hazard connected with men working up overhead and dropping plugs, pliers or other tools through the slots in the footwalk down to the stage floor. Of course, this latter condition also exists in studios where all the connections are made up on the floor and where the men hang scenery and top lights while working on scaffolds and ladders.

An advantage of the footwalks, forming part of the overhead system, which offsets all of the disadvantages and which appeals to every studio manager, is the facility for hanging scenery effects and lights from some sort of overhead fastenings. An ideal studio would be one having its ceiling constructed of a horizontal net work of steel ropes, the strands of which are capable of supporting

approximately 1,000 pounds every five feet. It is a known fact that the location of the hangings for overhead equipment including props, is always uncertain. The overhead footwalks and structural arrangement of this studio is equivalent to having the ceiling studded with eye bolts or the improvised horizontal network of steel rope. The overhead footwalks are very valuable as runways for the men to work on, but just as much so for the property men to hang their scenery and special lighting equipment.

V. Telephone Systems.

This studio is equipped with two distinct telephone systems, one consisting of a 20-trunk line, New York Telephone Company's PBX switchboard with its operators and approximately 150 extension instruments throughout the studio. The other system consists of a 200-line automatic switchboard and 100 extension instruments located throughout the studio and Laboratory Buildings. The automatic telephone system as is generally known, does not require any operators for making connections between extensions and has unlimited capacity so far as concerns the number of extension instruments which it will accommodate. The automatic switchboard equipment installed has an ultimate capacity of 200 lines, and was furnished and designed by the Automatic Electric Company and is similar in all respects to their PAX system now operating in several of the smaller cities throughout the country. No other automatic intercommunicating system available at the present time can accommodate as many extension phones as are installed in this plant.

VI. Fire Alarm System.

The building is completely protected by a combination watch and fire alarm system, stations of which are used ordinarily for transmitting signals by the watchman while making his rounds. These signals go to a central office outside of the plant, supervised by the local telegraph company, and logs are kept of the rounds made by the watchman which are submitted to the owners at the end of each week. In other words, the watchman is supervised and unless he sends in his signals regularly and periodically, the supervisor goes to the building to determine the cause for the irregularity. In case of fire, the same station is used, but a different type of signal is registered in the central office by means of which the supervisor knows it is a fire signal. He then communicates directly with fire headquarters, obviating the necessity of going to a fire alarm box on the street to send in the alarm.

VII. Miscellaneous Signal Systems.

On account of the large area covered by the studio and the difficulty in summoning principals who may be on the stage floor, to the telephone or otherwise, a special electric silent call system using an electric numerical monogram signal has been devised,

similar in appearance to the common carriage call used by theatres. The telephone operator will be provided with a U. S. E. M. selector type keyboard, which is arranged to light up monogram signalling panels located under the footwalks in the upper studio and at the same time giving a single stroke on a gong, attracting attention to the illuminated signal. By means of this special selector, numbers ranging from 1 to 999 may be set up without the use of the customary perforated cards and other complicated apparatus used with carriage call systems. An outstanding feature of this silent call system is the fact that one does not have to stop work to count the number of strokes on a gong in order to interpret the signal. It is merely necessary to glance up at the electric monogram to see whether or not the signal concerns one. The interference with the work on the stage is but momentary as compared to the gong and horn system used in many plants. The wiring for this system is quite simple and consists of 26 No. 14 wires and two No. 10 wires run as a single cable from the selector to the electric monograms. The current supplied is obtained from the house lighting circuits.

Another system of special signalling devices was installed in some of the private offices of the executives, operated by a foot push and lighting a lamp over the secretary's desk. By means of this signal, a principal can summon his secretary without detection or suspicion on the part of the visitor and the secretary can then either usher the visitor out or find a ready excuse for calling the executive away from his desk and in that manner dispense with the presence of an undesirable visitor in a polite and expedient manner.

VIII. Laboratory.

The Laboratory Building shown in Figure No. 15, receives its electric current supply over three different services from the main switchboard in the studio generator-room across the street. The Laboratory Building is supplied with alternating current, 220-volt, three-phase for the various motors and 220/110-volt alternating current for the lighting. There is also a direct current emergency feeder connected to the direct current bus bars on the main switchboard in the generator room which may be used for the printing lamps or the Cooper-Hewitt equipment on the cartoon and titling cameras in the Laboratory Building.

A 5½ K.W. motor generator set has been installed in the Laboratory Building to supply direct current, 118 volts, to the printing lamps on the film printing machines and to the Cooper-Hewitt lamps on the cartoon cameras. In order to keep this voltage at a constant value for printing, an automatic voltage regulator is employed, the details of which are familiar to most of us. The Cartoon Department in the Laboratory is rather unique. Each cartoon camera is operated by a small motor, which is started and stopped by means of a foot treadle. The sketching frame on the table directly beneath the camera is illuminated by Cooper-Hewitt "U" tubes on either side.

The Laboratory Building is equipped with a large number of connections for supplying alternating current to monoplane lamps and projection machines. The various circuits feeding the printing and perforating machines are run to distributing panels located outside of the actual work-rooms. The advantage of this arrangement is obvious when replacements of blown fuses are to be made and when one considers how difficult it is to do this in a dark room.

The Air Conditioning Plant in the Laboratory Building requires considerable power for driving the various refrigerating and pump machinery, all of which is supplied from the transformers installed in the studio building. There is also to be installed a breakdown emergency secondary service, which will supply a limited amount of current for both light and power into the studio and laboratory

Figure 15—Famous Players-Lasky Laboratory Building.

buildings in the event of a breakdown in the high tension supply of the main building.

A special feature installed in the Developing Rooms is the application of a small transformer for supplying low voltage to automobile type lamps which are protected in a transparent ruby waterproof casing and which are submerged into the tinting solutions to ascertain the color density of the solution. These are also used by the developers as hand lamps between the layers of film on the frames in preference to the regular ruby wall boxes for examining the density of the film. With this low voltage arrangement, a lamp of small candlepower can be used and the entire outfit is in such

flat and compact form that it can be contained in the palm of the hand.

The exhaust system in the Perforating Room is worthy of special mention. This system is made up entirely of threaded pipe fittings and no sheet metal ducts are used. This eliminates entirely air leaks and a great portion of the noise usually caused by the exhausting air travelling at high velocity.

In the Drying Room, the ten revolving drying drums are driven by two jack shafts, each jack shaft connected by a silent chain drive to a motor. Although each drum is not provided with individual drive, it is provided with a friction clutch so that it can be stopped without necessitating the stopping of the other drums, the jack shaft or the motor.

The projection machines used for inspecting film are each equipped with a foot treadle which operates a friction clutch so that the motor may continue to run but the film stopped, quickly and suddenly at any point at all for cutting, examining or notching.

Figure 16—Studio and Laboratory Building of the Fox Film Corporation, New York City.

FOX FILM CORPORATION STUDIO AND LABORATORY

I. General Description of Building.

The Fox Studios, Laboratories and Executive Offices are all housed under one roof in a four-story brick structure occupying the entire block from 55th to 56th Streets and 10th Avenue and running approximately 300 feet east on both 55th and 56th Streets, to the floor lamps, but the arrangement of the various pockets and

which is the largest single building in New York City devoted to the industry. The photograph shown in Figure No. 16 is a view of the building from the 10th Avenue side.

The lower floor is devoted entirely to the Film Laboratory and is operated as an entirely separate and distinct branch of the corporation. This Laboratory is one of the finest in the world and one is impressed upon first entering it by the great amount of white tile used throughout, for the ceilings, walls and floors. This part of the institution is absolutely dustless and practically fire-resisting.

The executive offices, scenario rooms, projection rooms, dressing rooms, restaurant, etc., take up the entire second floor.

On the third floor are the two studios, covering approximately 35,000 square feet of floor area, one studio measuring 275 feet in length by 100 feet in width by 22 feet in height, and a smaller studio measuring 105 feet in length, 96 feet in width and of the same height as the larger studio.

II. Source of Current Supply.

Electrically, the building is divided into three sections, Laboratory, Administration and Studio.

There are four different sources of central station supply, one alternating current 220/110-volt two-phase service for the Laboratory lighting and power, and three direct current 220/110-volt services for the Studio and other lighting. The combined capacity of the direct current services supplying the studio switchboards totals 13,000 amperes at 120 volts. The various services brought into the building are independent of each other so that the failure of one will ordinarily not affect the remaining services thereby enabling the studio to continue its work without interruption due to this cause. The alternating current in addition to supplying the motors on the Laboratory equipment also supplies the motors in the carpenter and machine shops, refrigerating, heating and air conditioning plants and ventilating system. The air conditioning plant alone consumes approximately 300 H.P. and is used to regulate the temperature and humidity for the developing and printing machines and for general conditioning of the laboratory air.

III. Feeder System for Studio Switchboards.

The Studio is equipped with six remote control switchboards quite different from those installed in the Famous Players-Lasky plant. These six switchboards are supplied by three main feeders arranged in a manner so that all the copper of these feeders is always in use and when the feeders are not carrying full load current the drop in voltage is practically negligible due to the fact that all the copper installed is in service all the time. This arrangement approaches as nearly as possible that of the bus bar system described in this paper.

IV. Studio Switchboards and Plugging Box Equipment.

The Studio is equipped with six combination manual and remote control switchboards, each measuring approximately 11 feet in length by 10 feet in height, enclosed and protected on all sides and top by wire grille work. The manual sections of the switchboards consist of double-throw knife-switches for feeding the various lines running to pockets on the side walls and overhead, and are supplied by a double bus bar system. Each of the double set of bus bars is controlled by master knife-switches of high capacity used for manual control of "effect" lighting. In addition to these master knife switches, each switchboard is equipped with from six to eight heavy-duty type remote control magnetic switches which are operated from the stage by the director or camera man in a similar manner to the remote control system described elsewhere in this paper. These magnetic switches are of high capacity in order to handle the heavy currents required by the special control and are each equipped with a vacuum dash pot device which eliminates practically all the noise occasioned by the closing and opening of the heavy contacts. It is obvious that this noise would be very objectionable on the stage floor and might interfere with the players and directors. These vacuum dash pots in addition to eliminating the noise, reduce the wear and tear on the remote control switches. The application of remote control switches to these special conditions and the special dash pots with which they are equipped, was under the direction and suggestions of Mr. Walter J. Quinlan, the electrical engineer for the Fox Film Corporation, who is also a member of our Society. In order to obtain the combination manual and remote control in this studio, it was necessary to sectionalize the main bus bars on the various switchboards and intercept each of these sections with a remote control switch of proper capacity.

The wiring equipment consists of heavy feeders to three-wire wall pockets located on the walls around the studio, each controlled by a double-throw knife-switch on its corresponding switchboard. Branch circuits of lower capacity run to the various overhead plugs for direct connection to the top lights without the use of spider boxes.

The system designed for the Fox Studios, while more expensive than any system ever installed in any studio in the world, is considerably more flexible than any other system.

Not only can the lights be remote controlled from the stages out on the studio floor for special effects, but when any change is necessary in the combination or number of lights, it is unnecessary to interfere with the plugging equipment or with the cable connections on the stage floor. To make such a change, it is merely necessary for the electrician to go to the corresponding stage switchboard and throw the various knife-switches connected to certain pockets on to the proper bus bar and proper remote control switch. The advantage of this feature is apparent since there are no overhead footwalks necessary in this studio and changes can be quickly made,

without interference to the sets on the floor and without one stage interfering with the other. The switchboards are also arranged so that several stages can be operated from the same board independent of each other without interference.

The top lights are hung from an overhead track system of the Louden make, fastened to wooden roof trusses and cross beams with a very complete system of switching frogs which enables the convenient transferring of top lights from one stage to the other.

The overhead rail system is of light construction and is "T" section in shape and weighs slightly over one pound per foot. These tracks are fastened with special adjustable suspension hangers every few feet. Although the track system is very light in weight, it functions more satisfactorily than any overhead track system yet designed for studios. The carriages which roll on these tracks are also light weight but are highly efficient on account of their ingenious construction and roller bearings. The top lights are hung from these carriages by means of small chain blocks used for raising and lowering as desired.

The total plugging equipment in this studio could supply 25,000 amperes at 120 volts if all were used at one time but this total capacity is unnecessary in the feeders since it will never be required simultaneously.

The control stations for operating the remote control switches consist of portable cabinets containing standard push switches arranged in gangs and function in a similar manner to the Monitor remote control station described in this paper. In addition to accomplishing the various features already mentioned in connection with the remote control station, each one of the stations used in this studio is equipped with an electrical lockout device which prevents operating certain buttons on the station which may be in use on another station by some other stage. This arrangement was necessary since an entire switchboard can be controlled from any single station or from a number of stations and provisions had to be made so that one station using only part of the switchboard could not interfere with the other.

V. Advantages and Disadvantages.

The various advantages of the overhead system have been previously described, but these advantages would not apply to this particular studio.

Since the height of the studio is limited and since the clear space from floor to roof trusses is utilized by the scenery, an overhead footwalk system was quite impracticable. In addition to this, the overhead top lights can be readily moved about on the studio floor by means of long poles so that the footwalks are unnecessary for this purpose. It is true that the cables are strewn on the floor from the various wall pockets to the spider boxes supplying current

switchboards is such that in very rare cases do the cables of one stage interfere with those of the other.

There is the disadvantage, of course, of the abuse to which the cables are subjected, but the easy means of making up connections and plugging-in without going up overhead seems to offset these disadvantages.

In regard to the fastening of scenery and props from overhead structural members, this is provided for by the timbers which support the overhead track and cross timbers used as stiffeners between roof trusses.

In making comparisons of an overhead equipment with that as installed in this studio, it has been the consensus of opinion that the system as designed here has worked out much more efficiently than an entirely overhead system on account of the peculiar conditions of the building.

In addition to the studio lighting equipment, a very complete system of work lights has been installed with controlling switches placed on each of the various studio switchboards.

A special system of watchman's lights has also been installed on the side walls around the studio, approximately 20 feet above the floor on pilot control, so that the watchman in making his rounds pushes the switch at one end of the studio aisle space and extinguishes that row of lights at the other end, lighting up the next row at the same time, and so on. With the installation of these lights, it is unnecessary to burn the work lights all night, thereby effecting a considerable saving in current consumption.

VI. Telephone System.

This Studio is equipped with two distinct telephone systems, one consisting of a PBX exchange switchboard connected with the New York Telephone Company's lines and approximately 200 extension instruments throughout the building.

The other system consists of an intercommunicating Dictograph system which provides intercommunication only between departments that have business with each other. For instance, some instruments can communicate with 25 different points, whereas others can talk to only three, or four or in some cases only one. This prevents waste of time in private conversation and keeps the lines always open for necessary conversations.

To accomplish all the features of an intercommunicating system, a very intricate net work of cross connections was installed and some of the executives' instruments are equipped with a special device for supervising conversations between various departments, cutting in to the system and obtaining right-of-way in preference to conversation which may be going on, and many other special signalling facilities.

VII. Fire Alarm System.

The building is completely protected by a combination watch and fire-alarm system, stations of which are used ordinarily for transmitting signals by the watchman while making his rounds. These signals go to a central office outside of the plant, supervised by the local telegraph company and records are kept of these signals which are submitted to the owners periodically. This part of the system is identical with that of the Famous Players-Lasky Corporation's system. However, the fire alarm part of the system is somewhat different from any which have heretofore been installed in a building of this type. It is generally known that a fire in a film building, no matter how small, causes considerable excitement and panic amongst the employees and very often in film laboratories, the actual damage by a small fire is nil compared to damages caused by turning on the "white" lights in the various developing and printing rooms or by the developers running out of their rooms and leaving the film in the tanks. This condition has been ingeniously provided against by Mr. Quinlan in designing the fire alarm system, so that the first alarm sounded from any box is received only by the chief mechanic in charge of the laboratory. He then investigates the fire and if it is a serious one, goes to the nearest station and sends in either an alarm summoning the people in the laboratory only, or an alarm summoning the people in the entire building.

The fire alarm in addition to recording at the telegraph company's headquarters, also sounds gongs distributed throughout the building. This system as applied to other industries is known as the dual operation system, but no dual system at the present time functions as completely and efficiently as this one.

VIII. Laboratory.

The Laboratory Department, as mentioned before, is considered one of the most complete in the country and is equipped with all the up-to-date devices known to the art.

For the printing lamps, special motor generator sets are installed and arrangements have been made so that when special night work is necessary on only one or two printing machines, a smaller motor generator set is run in preference to a larger one for maximum efficiency.

The projection rooms in the Laboratory, contain, without doubt, the largest amount of equipment of any projection department found elsewhere and are equipped with both alternating and direct current feeders so that either arc lights or monoplane lamps may be used. In addition to the laboratory projection rooms, a private projection room has been fitted up for Mr. Fox which contains practically every device used by the projectionist in a large theatre. A system of intercommunicating, loud speaking telephones is installed between the projectionist and the projection room for private conversation and discussion between the projectionist and Mr. Fox while the picture is being reviewed on the screen.

In conclusion may be stated that the advent of the mammoth studio into the motion picture industry for quantity production and maximum efficiency, when compared to the smaller studios of the past, will present many more interesting engineering problems which will be developed in studios of the future and will require the services of the engineer rather than those of the non-technical studio personnel of the past.

Acknowledgment and thanks is tendered at this time to the various principals in the Famous Players-Lasky and Fox Film Corporations and also to the various manufacturers, many of whom are represented in our Society, who have given their time and the benefit of their experience to the author in the preparation, design and installation of the electrical equipment in these two incomparable projects.

Portable Power Plants for Motion Picture Studios

By H. F. O'Brien

Synopsis

SO many different elements of design enter into the construction of the portable power plants used for studios that it would be impossible to attempt to bring all of their numerous advantages before you in a short paper. It is the author's hope that by bringing before you the most important improvements in this branch of Motion Picture Engineering, you would have a better understanding of the problems involved and should any member contemplate the construction of such an equipment he could at least derive some benefit by learning of the experiences of those who pioneered in this particular branch of the Motion Picture Industry.

Outline

1. Introduction.
2. Two kinds of portable plants—Gasoline Engine and Electric.
3. Discussion of engine-driven equipments.
   (a) Principal requirements.
      1. Portability.
      2. Continuity of service.
   (b) Results obtained from first equipments.
   (c) Comparison of horse-power rating.
4. Some features of design of equipments now under course of construction.
   (a) Using two generators.
   (b) Cooling systems.
   (c) Self-starters.
   (d) Voltage and speed regulation.
   (e) Carburetors.
   (f) Methods of mounting.
   (g) Switchboard equipment.
5. Discussion of Portable Electric Power Plants.
   (a) Three-Unit Induction Motor Generator Set generally used.
   (b) A.C. Switchboard and Metering Equipment.
   (c) D.C. Switchboard.
   (d) Electric equipments generally mounted on trailers.
6. Conclusion.

When the production of motion pictures was an infant industry, the scenes were almost entirely taken in natural sunlight. Because of the fact that Southern California is blessed with an abundance of sunlight several of the producing companies located there. It

was not long before conditions changed materially. More and more productions were made in enclosed stages and more and more intense artificial illumination was employed until at the present time nearly all large motion picture productions are made in enclosed stages, and more attention is being given to the proper illumination of exteriors and night scenes.

This improvement in the illumination of exteriors and night scenes presented many obstacles that had to be overcome, but the engineers and electrical departments are in the habit of solving the many and complex problems that arise in their everyday routine, and the problem of illuminating night scenes and locations has been quite successfully solved by using a portable electric generating plant of sufficient capacity to properly illuminate the setting.

This idea originated in the Western Studios where Mr. Harry Brown, electrical engineer for the Universal Film Man. Corp., constructed in 1915 a portable engine-driven plant of about 50-kilowatt capacity. At the present time every large western studio has one or more of these portable plants which they find indispensable. Inasmuch as nearly all of Southern California is covered with a network of high-tension electric power lines the studios have mounted motor generator sets on trucks or trailers so that they may be easily transported to "locations" where electric power is available.

Since the portable engine-driven outfits were used first and since they enjoy more general use on location work, we shall consider them first.

It is obvious to anyone that any portable power plant must meet the two principal requirements of portability and continuity of service. Those of experience will realize that these two apparently simple requirements present some perplexing problems to solve. It is not so difficult to design an outfit that may be comparatively light in weight and easily transported but generally the disappointing feature of such an outfit is that it will not give continuity of service under the severe conditions imposed by the application. The reverse is also true; i. e., that a heavy outfit with a good reliable gasoline engine could be constructed but it might prove very unwieldy and difficult to transport to the summit of some mountain where such outfits are often used.

The most common error in the earlier equipments was that the engine proved too small. Although some of these engines were rated as high as 200-H.P. by the manufacturers, actual results showed this rating to be excessive.

The most successful equipments now in operation have profited by the sad experiences of those who built the earlier equipments and have equipped their outfits with sufficiently large engines to insure satisfactory operation when the generator is fully loaded. It is interesting to note that a generator normally rated at 35 kilowatts will stand about all the load that the average gasoline engine rated at 150-H.P. can pull. If the engine was rated on a basis of actual horsepower over a 24-hour period, as the generator is, it would, of course, require only approximately 51 H.P. to deliver 35 kilowatts.

Past experience has demonstrated to the large western studios that it is almost useless to have a portable gasoline electric equipment unless it can be depended upon at all times. There are under construction at present in Los Angeles, about six of these equipments on which the studios are sparing no expense in their efforts to have them entirely successful.

Five of these outfits are being equipped with the famous Liberty engine used for aeroplanes. Slight alterations have been made in these engines; for example, the weight of the pistons has been increased, self-starters have been added, etc.

The author in a previous paper explained the advantages of the three unit motor generator sets which he recommended for studio application. It is gratifying to note that several of the studio elec-

Portable Gasoline Electric Equipment of Thos. H. Ince Studios, Culver City, Calif.
180 P. Seagrave Engine, 75 K.W. Westinghouse Generator

tricians have from past experience found this scheme of using two 115-volt generators connected in series, so satisfactory for their 3-wire, 115-230 volt systems that they are carrying out this idea in their portable equipments.

In the equipments now being constructed these Liberty Engines having a normal rating of 434 H.P., at 1650 R.P.M., will be direct connected by means of flexible coupling to 2-50 K.W. generators built into one frame and tandem connected on a single shaft. These generators are designed to carry heavy overloads for short periods and should prove well adapted for this service. The normal speed of these outfits will be 1100 R.P.M., at which speed the engine has a rating of approximately 320 H.P. The weight of the Liberty engine store is only 903 lbs.

There is a considerable amount of accessory equipment supplied on these portable sets and if one hopes to obtain successful results

from the completed unit he should give considerable care to the selection of these accessories. Probably the most important of these is the cooling system. It is necessary to use a very large radiator of the best design and provide a forced draft for it, as this outfit is stationary when in use and the radiation due to natural air circulation would be insufficient. The Metro Pictures Corporation is building one of these outfits and will have the blower fan driven by a series motor so that the operator in charge can vary the speed of the fan over a considerable range to keep the circulating water at the proper temperature as indicated by a thermometer.

It is very convenient, of course, to have some means of starting these large engines, other than by hand cranking. This is generally done by an electric starter as on an automobile although the Winton Engine Works supply a very satisfactory air starter which, of course, eliminates the necessity of transporting and charging storage batteries.

Large tanks should be provided for carrying ample quantities of water, gasoline, and lubricating oil, and these should be placed out of the way and piped so that the various liquids can be used where desired without requiring any handling.

Close voltage regulation is just as much desired on these portable equipments as it is on the motor generator sets in the Studio Substation, but it is somewhat more difficult to obtain. Some engine manufacturers supply a very good mechanical governor which actuates the throttle valve and will keep the speed of the engine constant within a range of about 5%. If this result can be secured it would, generally speaking, be satisfactory, but the author has seen some regulators designed by the studio electricians where a solenoid coil actuated by the generator voltage operated the throttle valve, giving excellent results. The first Liberty outfit to be completed is equipped with a governor built on the dynamometer principle and will regulate within 2%.

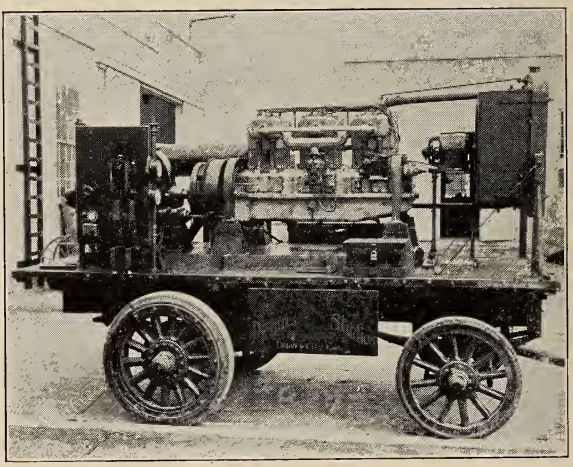
At least one of the studios seem to consider this matter of voltage regulation so important that they are also equipping the generator with an automatic voltage regulator which regulates the field current so as to produce very close voltage regulation over wide ranges of load.

One of the most important items to consider is the carburetor, which to be satisfactory on this application, must have the following characteristics:

1. It must accelerate quickly.
2. It must not choke or load up.
3. It must not be sensitive to changes in temperature, or altitude.
4. It should not have many delicate adjustments.
5. It should not be subject to changes in adjustment, caused by the vibration of the engine.

Those having had experience with carburetors will realize that while there are several carburetors of good reputation on the market there are very few that will meet all of the above requirements. There is at least one such carburetor manufactured in Los Angles, which, when properly adjusted on the initial test requires no further adjustments for altitude or temperature and gives excellent carburetion without the use of any needle valves or spray nozzles, a feature which makes it very successful on these portable power-plants.

There is room for some argument as to whether these gasoline engine driven sets should be mounted on a trailer or on a truck, but, generally speaking, these outfits should be designed so that they can be used in out-of-the-way locations where it is impossible to obtain any other power. Experience has shown that it is worth while to purchase a first class truck with its own motive power and a multi-



Portable Gasoline Electric Equipment of Goldyn Pictures Corp., Culver City, Calif.
6 cyl., 90 P. Wisconsin engine, 35 K.W. Generator.

speed transmission that will give a large gear reduction so that mountain roads can be negotiated without difficulty. Some studios have purchased trucks having all four wheels power-driven.

These portable outfits are built in all sizes from 20 to 100 K.W. capacities. In the smaller sizes up to about 25 K.W., some very successful equipments have been built using the chassis of some first class high-powered automobile. In these cases the generator is chain-driven from the automobile engine. A separate clutch being provided so that the generator may be disconnected while the outfit is in transit.

On these small equipments it is, of course, advisable to use pneumatic tires but on the large outfits weighing five to six tons complete, solid tires are most satisfactory.

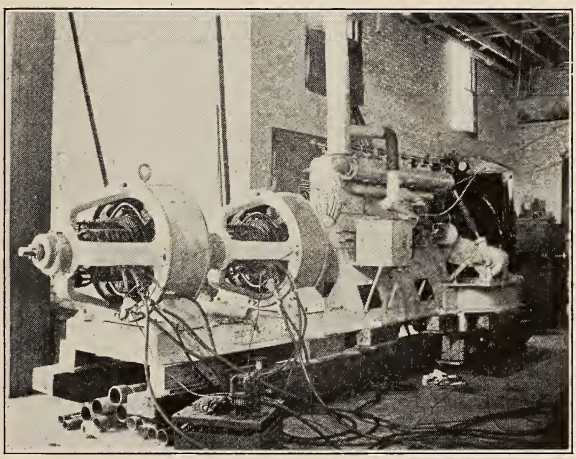
The switchboard equipment for these portable plants is very simple, consisting of a small panel having mounted thereon, ammeter, voltmeter, automatic carbon circuit breaker, field rheostat, generator switch, and outgoing cable or bus bar terminals. Where two generators are used two single-pole carbon breakers, two pole generator switches, two ammeters, and two field rheostats are employed.

Unfortunately at the time this paper was written none of the large portable plants using Liberty engines had been completed so that it is impossible to show any photographs or results of tests on these sets, but the first of these outfits was being tried out by Marshall Neilan on location in Glacier National Park, Montana.

The first electrical equipment for any studio in Japan was recently sold and consists of:

One 8-cylinder 200 H.P. Winton engine, direct connected to

Two 50 K.W. type "SK" Westinghouse generators, all of which are direct connected and mounted on a common base. The radiator



100 K.W. Engine driven generating equipment for Shochiku Kinema Co. of Tokyo, Japan.
200 H.P. Winton engine 8-cylinder, 2 - 50 K.W. Westinghouse Generators, 125 volt.

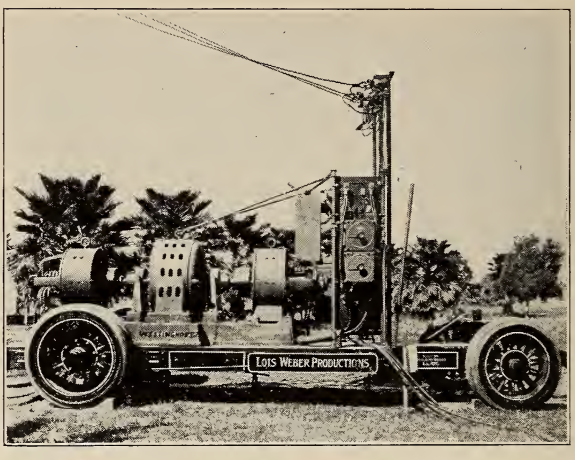
and blower fan are also mounted on the same base and mechanically connected to the engine. While this outfit is not intended for portable purposes, the engineering features are practically identical with a portable outfit.

The electrically driven sets have many points in common with the gasoline driven equipments—they must be easily transported, capable of standing heavy overloads for short periods, and the voltage regulation must be good. From an electrical standpoint, they must be so designed that they can be used on all of the power lines in their home territory at least, and be provided with proper protective devices on the alternating current side. Metering equipment should also be provided for metering the A.C. power used.

Lois Weber Productions have had the 100 K.W. portable electric plant, illustrated below, in use for one year and are greatly pleased with the results. This outfit which is one of the largest and best designed in use at the present time might be described in detail to give you a good idea of these portable electric motor generator sets.

This set is a three-unit, Westinghouse equipment, consisting of a 200 H.P., 3-phase, 2,200-volt, 50-cycle, 6-pole induction motor, direct connected to and mounted on the same base with two 50 K.W., 115-volt, flat compound wound, interpole generators.

On the forward end of the trailer are mounted the switchboards and incoming power line structure. The California State Accident Commission requires that the 2,200-volt connections to the power line must be at least twelve feet above ground, so a telescope pipe frame-



2 - 50 K W., 120 volt Westinghouse type S.K. Generators.
Portable Motor Generator Set of Lois Weber Productions,
Los Angeles, Calif.
1 - 50 P., 3 phase, 2200 volt, 50 cy. Westinghouse motor.

work was designed, which could easily be set up on location and readily taken down while the outfit was in transit.

Mounted on the upper cross-arm of this pipe framework are three high-tension fuse blocks, to which are connected the long flexible leads, used for attaching to the 2,200-volt power lines. The power is then conducted down in conduit to the oil circuit breaker ahead of the auto-starter. This oil circuit breaker provides protection for the motor while the auto-starter is in the starting position The auto-starter is provided with automatic overload and no-voltage protection.

The metering equipment, consisting of the ordinary type of polyphase integrating watt-hour meter, with potential and current transformers, is placed in an enclosed steel cabinet. This meter is tested by the Power Company at certain intervals. In this manner

accuracy is assured and it greatly simplifies matters for both parties by avoiding disputes regarding the power consumed.

In all Southern California it is possible to obtain three-phase, 2,200-volts, 50-cycle power without difficulty, so that all of these portable electrical plants are designed for that voltage on the A.C. end.

The direct current switchboard is also mounted on the forward end of the trailer, the A.C. and D.C. boards facing each other, a space of approximately 30 inches being left as a passage-way for the operator in charge. This direct current-switchboard is standard in every respect. Generally, only one feeder circuit is used so that only a generator panel with a single set of automatic carbon circuit breakers is necessary. Bus bar terminals for the outgoing feeder cables are provided on the rear of the direct current switchboard. All of the wiring is placed in conduit making it safe. The insulating oil used in the 2,200-volt auto-starter and circuit breaker can be drained into a tank under the floor of the trailer and pumped back again by means of a hand pump. This is necessary to prevent the waste of this oil due to splashing while the outfit is in transit.

You will note from the photographs that this layout is neat in appearance, convenient, and safe. When the outfit is not in use on location it is taken into the studio sub-station, where the A.C. and D.C. cables can be connected to it in a few minutes. In this manner, it becomes a very efficient and economical piece of apparatus for the studio.

While the gasoline-driven plant might prove too expensive to operate in the studio in competition with electric power, it has proven its worth out on the desert or up on a mountain or some other place where the necessity for power lines has not yet arisen. Both the electric and gasoline-driven portable power plants have their place and the fact that all the large western studios have them is convincing proof of their value to the motion picture industry.

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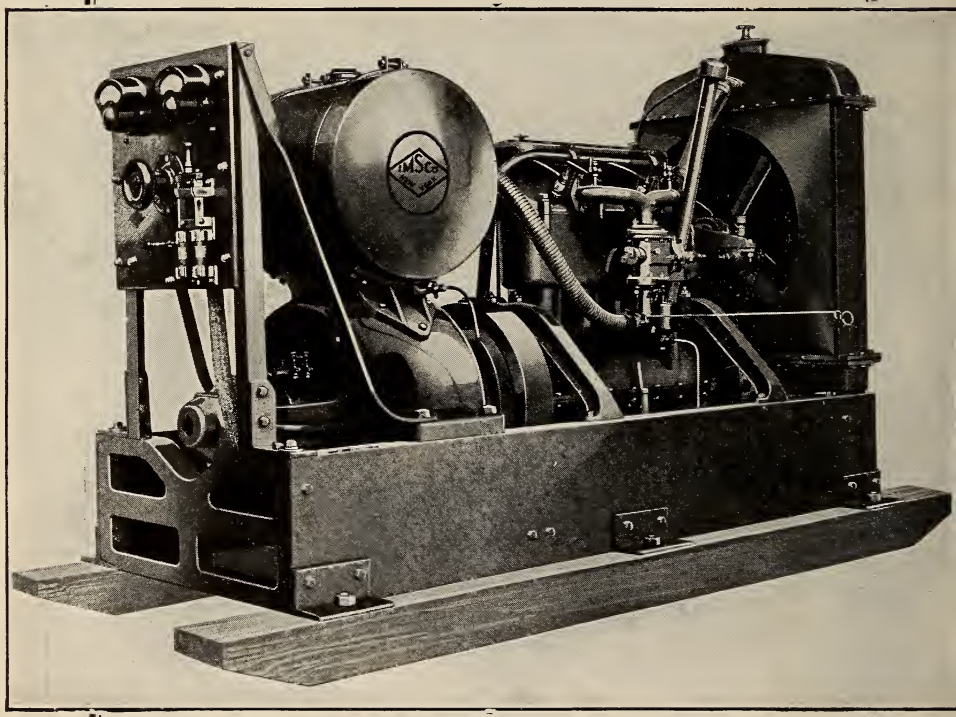

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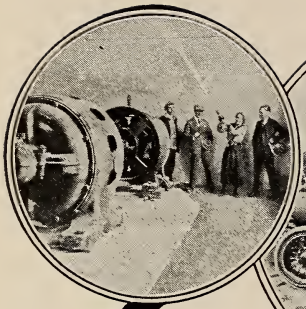

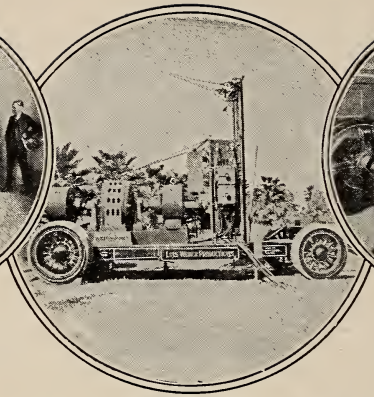

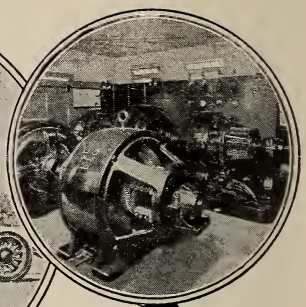

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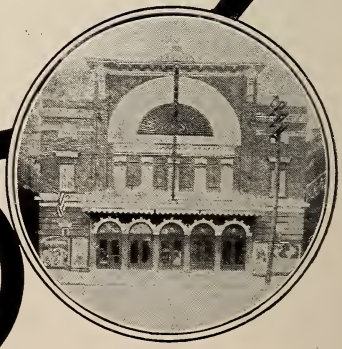

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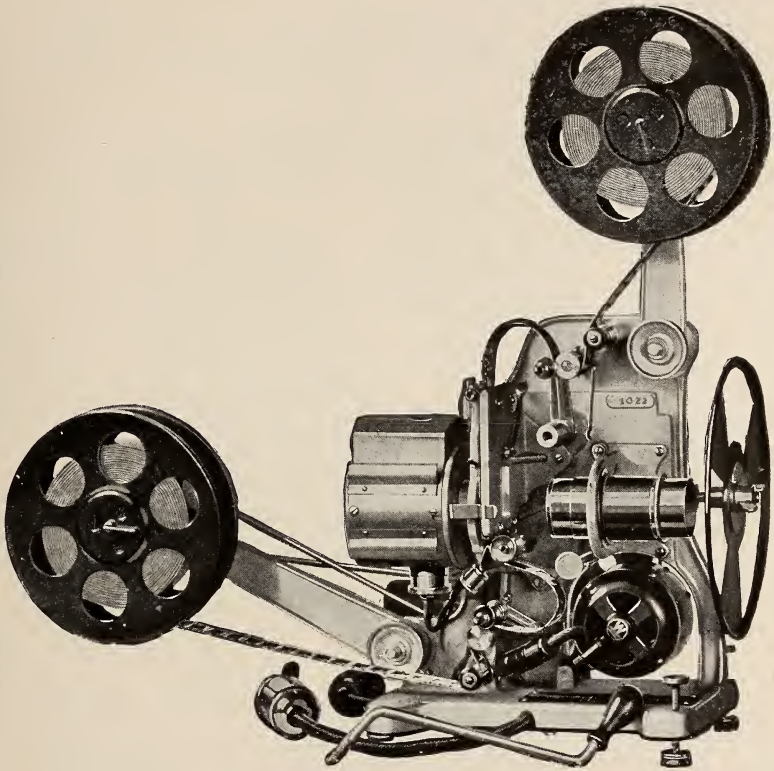

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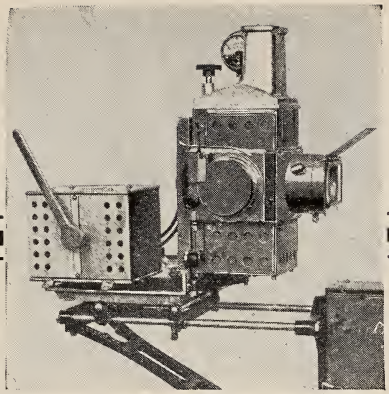

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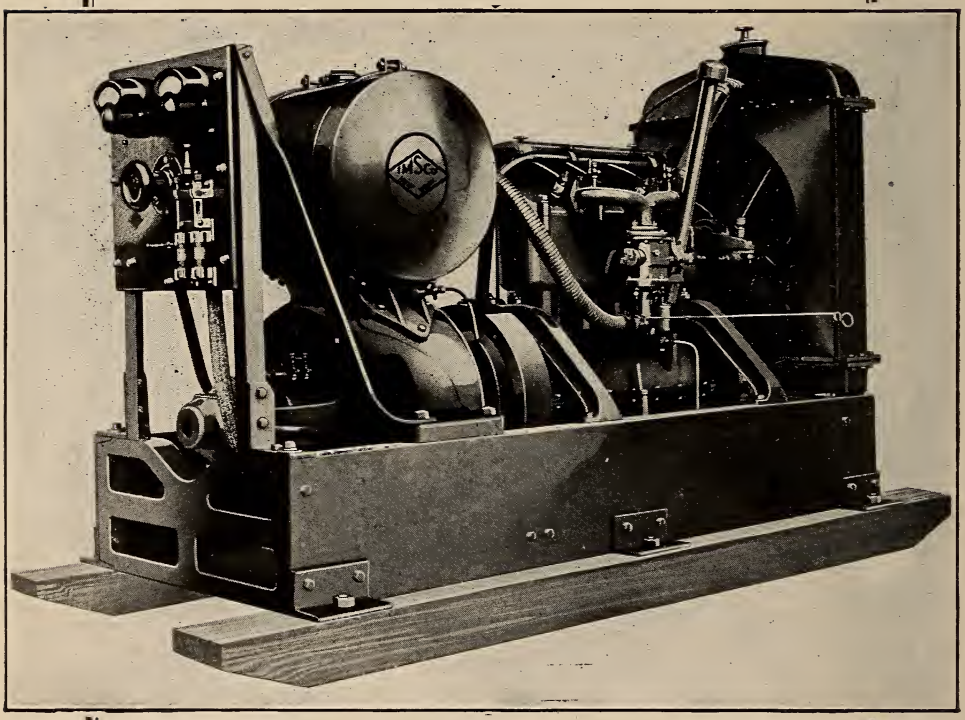

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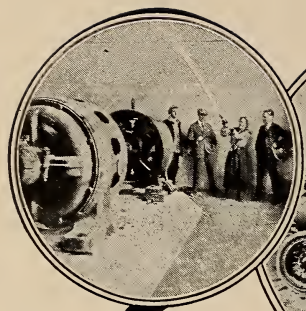

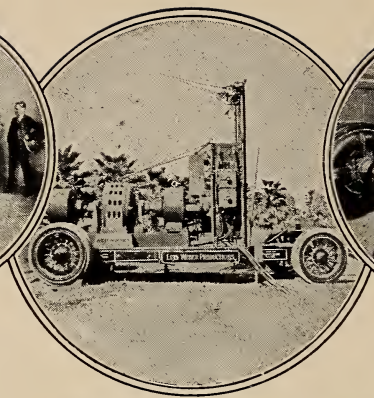

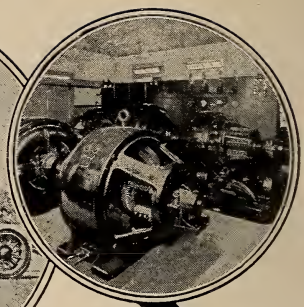

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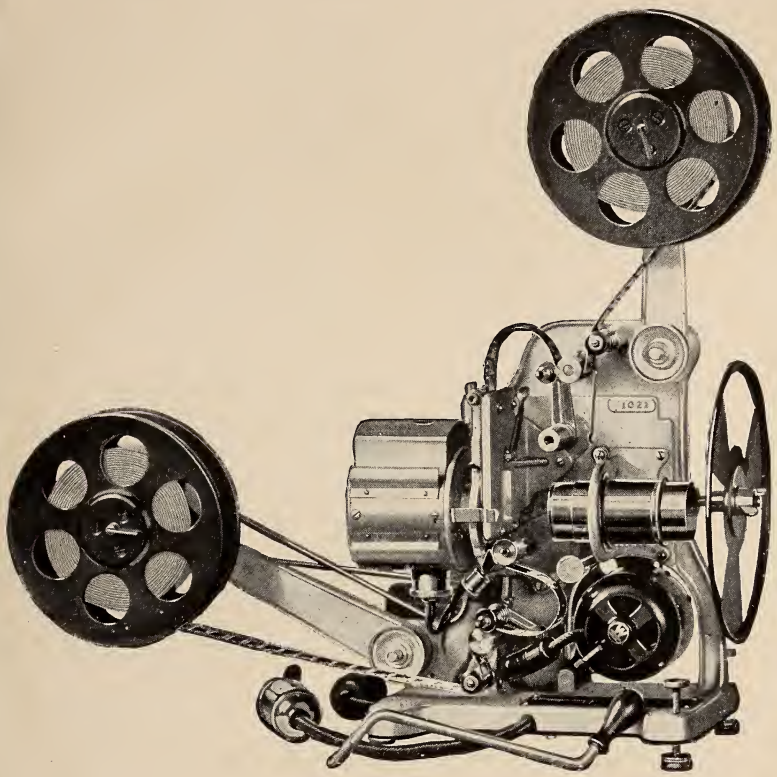

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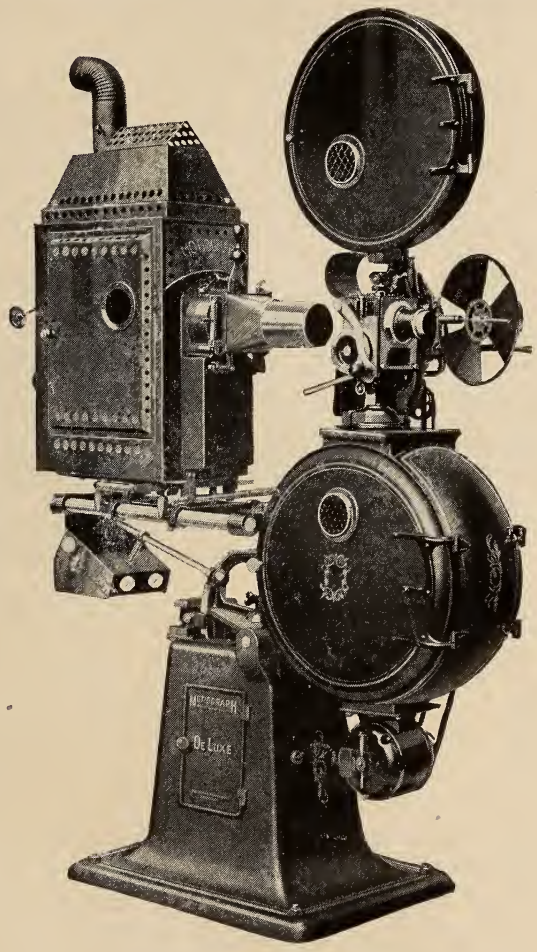

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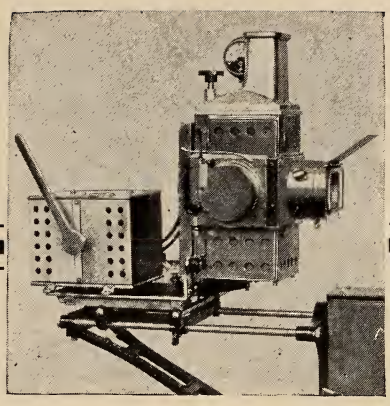

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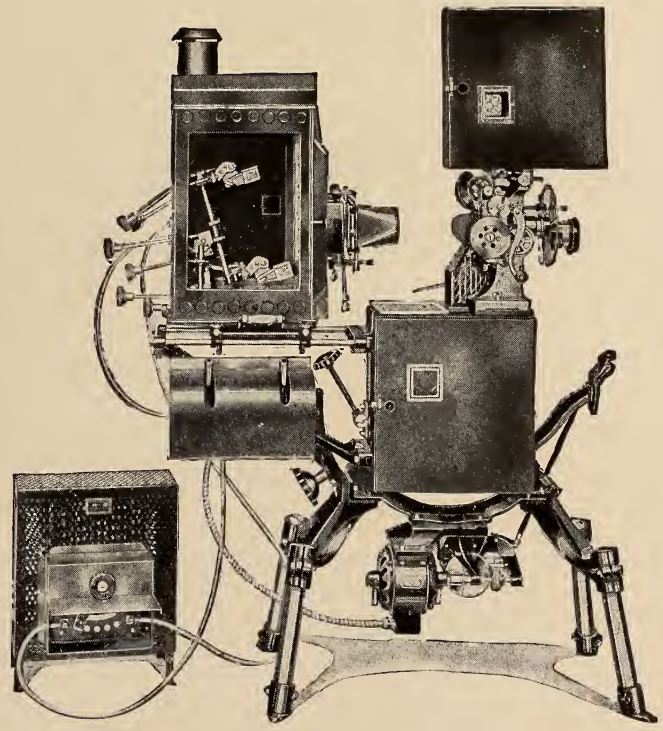

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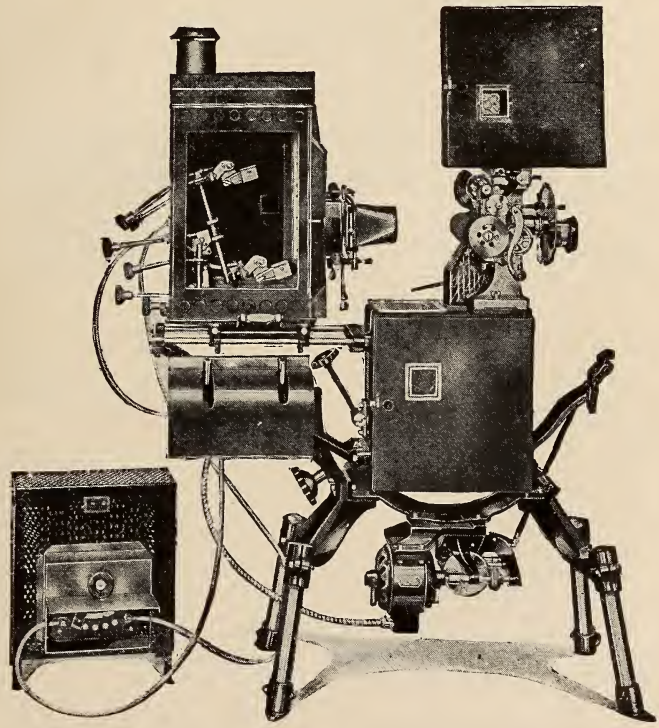

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